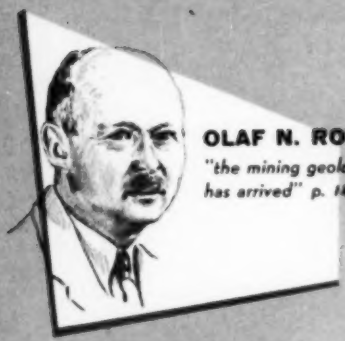
MINING ENGINEERING

FEBRUARY 1952



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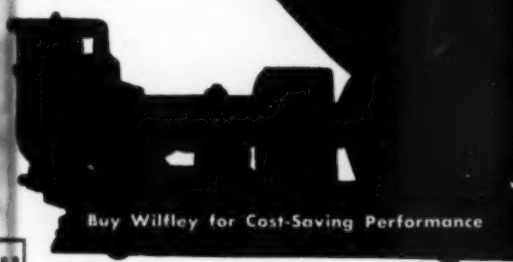

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VOL. 4 NO. 2 FEBRUARY, 1952

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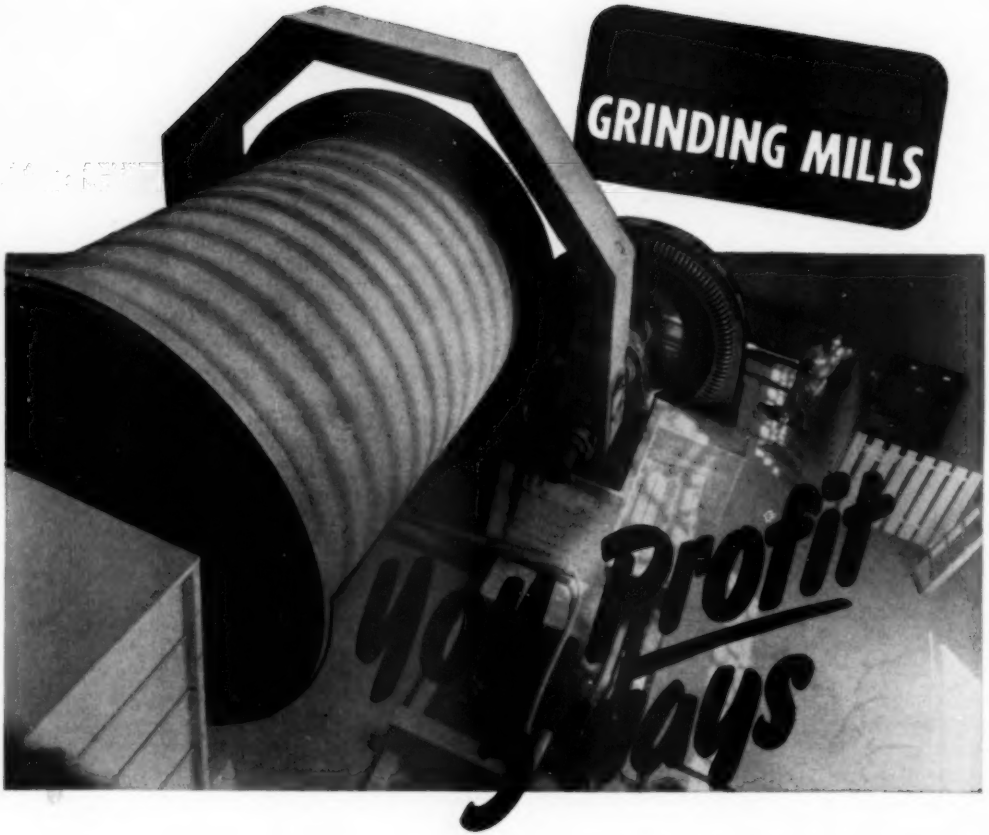

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Letters to The Editor

Shortage of Engineers Can Be Cured

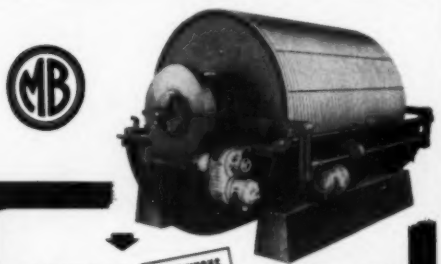
The engineering personnel shortage, present and impending, so well brought out in the article in *Mining Engineering* in the August, 1951 number, both in the editorial lead and the article by William B. Plank and Henry J. Petrie, has left untapped and has ignored a potential source of supply that would fill the need ably and with complete satisfaction. This source is comprised of the women engineers and geologists, both presently trained and able to handle work at all levels, and the many who would make splendid engineers and geologists if they could hope for even a modest taste of the square deal that should be theirs, but, as we all know, is not.

I write from experience. It is not pleasant or sensible to have to urge borderline cases among men students to consider engineering and geology as careers to fill the need, when I have far more able, interested and suited young women students whom I must divert into other channels. It does not make sense to scrape the bottom and sides of the barrel to induce potentially second or third rate male engineers and geologists to enter the profession when we have superior material among the women, eager to do good work in these fields. It does not make sense for these men to become second or third rate in these fields when they might be first rate salesmen, musicians, advertising copywriters or policemen. Nor does it make any more sense to force potentially first rate female geologists and engineers to become second or third rate and very frustrated typists, kindergarten teachers, dress saleswomen or clerks.

At this point I am willing to admit that where superstitious miners object to women in underground workings, men are available for the jobs. Moreover, it is not necessary for women to be sent into the most difficult country if there is reluctance on either side of the contract. There may be fewer of them eager for the roughest assignments, in proportion to the men, but women are so accustomed to discrimination far more complete than that against any racial or religious group, that a reasonably tough assignment would seem like a heaven-descended joy. In my own experience, I have found that my girl students majoring in geology, could keep up with me in the field in the roughest terrain, but the men, all but the best students and the most physically fit young men, complained that they could not keep up with me and that I always "walked their legs off". The women, a few men and I always returned with bags heavy with well chosen specimens and proper notes. Most of the men carried no specimens and but poor scraps of notes on loose bits of paper. Yet the men were urged to prepare for a career in engineering or geology if their examination marks were reasonably good.

When we find that we still have a shortage of engineers and geologists after putting all the qualified women to work, then we may begin to worry. Until then, we are simply fooling ourselves as we wander in a forest of outmoded tradition and emotional habit reactions.

MARY W. GARRETSON
ASSOC. MEMBER, AIME
SCARSDALE, N. Y.



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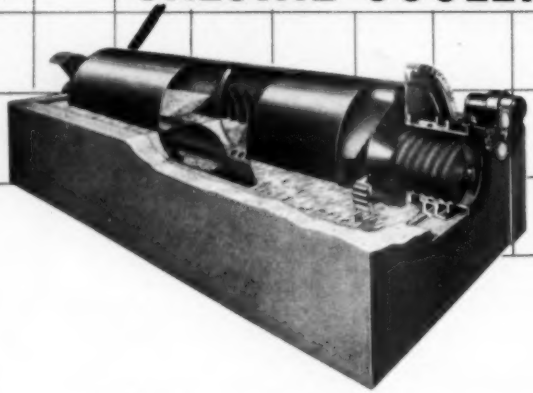

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Meet The Authors

A. B. CUMMINS

A. B. Cummins *(Industrial Minerals Review, P. 164)* was born in Los Angeles, Calif. and attended the University of Chicago and University of California. He received a B.S. and Ph.D. degree. He has worked at University of California and as a development and research engineer with Celite Co. He is at the present manager of research at Johns-Manville Co. in Manville, N. J. Dr. Cummins is an AIME member and has presented previous papers before it. He resides in Bound Brook, N. J.

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D. R. MITCHELL

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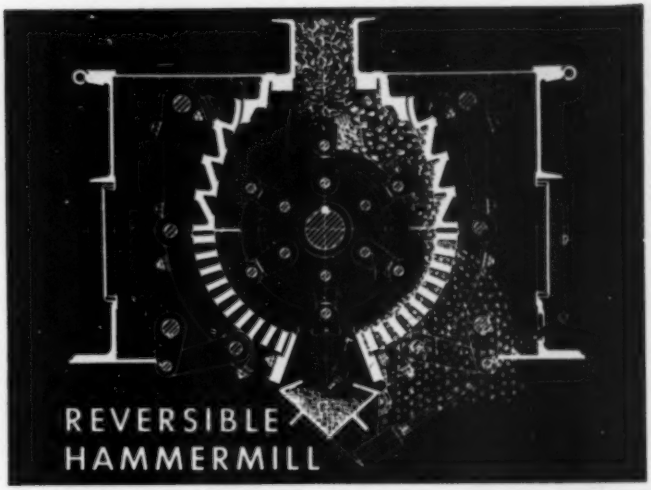
LEROY SCHARON



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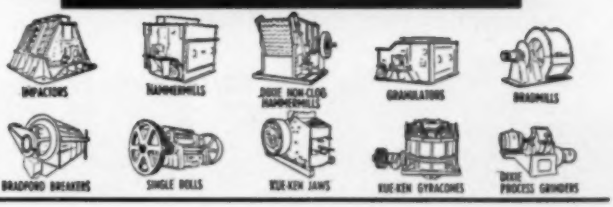

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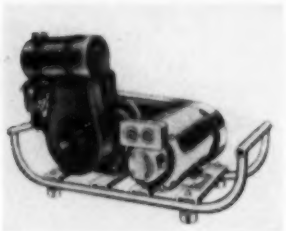

vibration dampener as well as an expansion joint and connects misaligned couplings and insulates flanges electrically. End flanges of the joint are French-type envelope gaskets made integral with the joint for easy assembly between companion flanges and a tight, leak-proof seal on installation. **Circle No. 1**

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abrasion by rocks during back-fill is important. It is also used for protecting and insulating cable and high tension leads subject to wear, abrasion and rough handling, and for bus bars carrying high voltage. The tape has a black, vinyl plastic backing that is 20 mils thick. It has a dielectric strength of 22,500 v, an insulation resistance of 200,000 megohms, and an electrolytic corrosion factor of 1.0. **Circle No. 4**

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Steelcote stainless steel coating for metal surfaces offers protection against rust, corrosion and other types of deterioration caused by salt air and water, industrial atmospheres, alkalis, most strong acids, heat, cold and sunlight. It is applied by a brush or spray gun and is packed in 1 and 5 gal containers. Machinery that should be made out of stainless steel but isn't due to present shortages can now be coated with stainless steel. Surveys indicate an unprecedented interest in stainless steel coating from those industries where the problem of surface maintenance is great. Manufactured by *Steelcote Mfg. Co.* **Circle No. 5**

Electric Generators

Wincharger Corp. recently announced the development of new portable gas-engine driven electric generators, Model 1800, in three general ratings—1000, 1250, and 1350 w at 115 v, 60 cycles, ac. They are suitable for the power requirements of building contractors, portable power tools and emergency operation. These generators are said to be rated conservatively and are equipped with sealed ball bearings for long life. It is claimed that the belted construction cushions shock to the generator, reduces vibration and increased the generator life. The unit is equipped with a universal mounting base which permits mounting any one of several popular makes of engines. **Circle No. 6**

Quick Setting Cement

This new compound sets anchor bolts for permanently fastening machinery, hand rails, or equipment of any type to concrete. Por-Rok, quick setting cement, replaces critical lead and sulphur for most bolt-setting operations. It is simple to use and involves drilling a hole, setting bolt in place, mixing Por-Rok with water and pouring into opening around bolt. Within 15 to 30 min, the bolt is anchored permanently. *The Hallemite Mfg. Co.* **Circle No. 7**

Mining Engineering **February**

29 West 39th St.
New York 18, N. Y.

Please send me { More Information ☐ / Free Literature ☐ / Price Data ☐ } on items indicated.

1	2	3	4	5	6	7	8	9	10
11	12	13	14	15	16	17	18	19	20
21	22	23	24	25	26	27	28	29	30

Students are requested to write direct to the manufacturer.

Name..... Title.....

Company.....

Street.....

City and Zone..... State.....

Free Literature

(8) DRILLS: *Cincinnati Lathe & Tool Co.* has recently issued a bulletin covering the C-O 16 in. 3000 sliding head drill. These drills incorporate a firm, substantial semi-steel cast base that is a self-contained foundation for the drill and also a coolant reservoir. Gibbed, dovetailed ways are cast integrally with the column to function as slides for the work table. The ways are machined and hand-scraped to an exact fit. A built-in telescopic square jack raises and lowers the table. A lever, located conveniently for the operator is used to lock the table securely at any desired position on the ways. Floor drills are available with one, two, three, four or six spindles.

(9) MINE JACKS: *Duff-Norton* mine roof jacks are safe and sturdy for supporting mine roofs, cross timbering and protection of working face areas. They are time and space savers when used as temporary roof supporting jacks in and around coal loading or conveyor machinery and for positioning mine machinery. Nuts and nut seats are snugly fitted on top of center columns of hot rolled steel tubing. Roof jack fittings are popular for cross timbering and supporting mine roofs at varying heights. These fittings enable you to make mine roof jacks to any desired height, by cutting 2 in. pipe to lengths desired, and quickly attaching them to base and top fittings, thus eliminating the necessity of stocking roof jacks in various heights.

(10) HYDRAULIC FLUID: A 12-page booklet describing in detail the properties and performance of Pydraul F-9, *Monsanto Chemical Company's* nonflammable-type hydraulic fluid, has just been issued. The fluid, developed primarily for use in such equipment as die-casting machines, hydroelectric turbines, glass drawing machinery and hydraulic presses, is finding wide application in similar operations where a flammable pressure transfer fluid is a hazard. In addition to chemical and physical characteristics of Pydraul F-9, the booklet reports with charts and pictures on tests demonstrating the fluid's fire resistance, noncorrosiveness, chemical stability and pumpability.

(11) ROCKER SHOVEL: This booklet describes the *EIMCO* 104 rocker shovel. This sturdy, crawler-mounted shovel requires a width of only 6 ft 6 in. It digs rock, sand, gravel or debris spilled along the highway by rock slides and winter sluff. The operator controls the speed and throw of the bucket load. Haulage units may be loaded from the side or end. On highways in order not to block traffic, trucks are loaded from the end. The truck driver keeps his truck within easy loading distance. Following the loader, reduces tramming time and speeds loading.

(12) MAGNETIC SEPARATORS: Jeffrey magnetic separators are exclusively of the drum type, which has the advantage of simplicity. The drum, which is a simple cylinder constructed of non-magnetic materials and is water-tight, is the only moving part. Drum rotation is independent of magnet pull. There is no danger of stalling the machine as may occur in machines where belts slide over the pole pieces. Gear motor and chain drive are recommended for each individual separator, but multiple installations may be driven from line shafting if desired. A motor support bracket is provided on all units. Capacities are dependent upon the fineness of feed and the nature of application. Manufactured by *Jeffrey Mfg. Co.*

(13) PRODUCT MANUAL: This booklet describes by pictures, graphs and lists specifications of *Caterpillar* scrapers, diesel tractors and their cable controlled and hydraulic controlled bulldozers. The Caterpillar No. 46 hydraulic control is designed for use with D8, D7 or D6 tractors. It is used for hydraulic bulldozer operation and is adaptable to other hydraulically controlled applications. Special seals are used to keep foreign materials out of the closed hydraulic circuit. Special vane type pumps are integral with the tank. Fast, responsive control, with raise, hold, lower and float positions, assures operator satisfaction.

(14) FAN-COOLED MOTORS: Construction details of Allis-Chalmers totally-enclosed, fan-cooled motors are described in a new bulletin released by the company. Construction features of the motor, which can be mounted anywhere, include a rigid cast iron frame which resists corrosion and holds bearings permanently in alignment, double insulated stator, improved heat dispersal, rotating seals on both ends of motor, and roomy conduit box. Due to the elimination of internal air passages and dirt catching pockets, the motor is easy to keep clean. This feature, together with a cooling system, makes the motor suitable for use where there is dust, dirt, snow or corrosive gases. *Allis-Chalmers Mfg. Co.*

HARDHED
Diamond
DRILL BITS
J. K. Smit manufactures the largest variety of diamond bits to give you the lowest cost per foot under all drilling conditions.
HARDHED matrix for the usual drilling conditions.
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PERFET impregnated bits where this type gives better performance than surface set diamond stone bits.
J. K. Smit engineers welcome the opportunity to discuss your drilling problems. Special equipment can be made to meet any unusual conditions.
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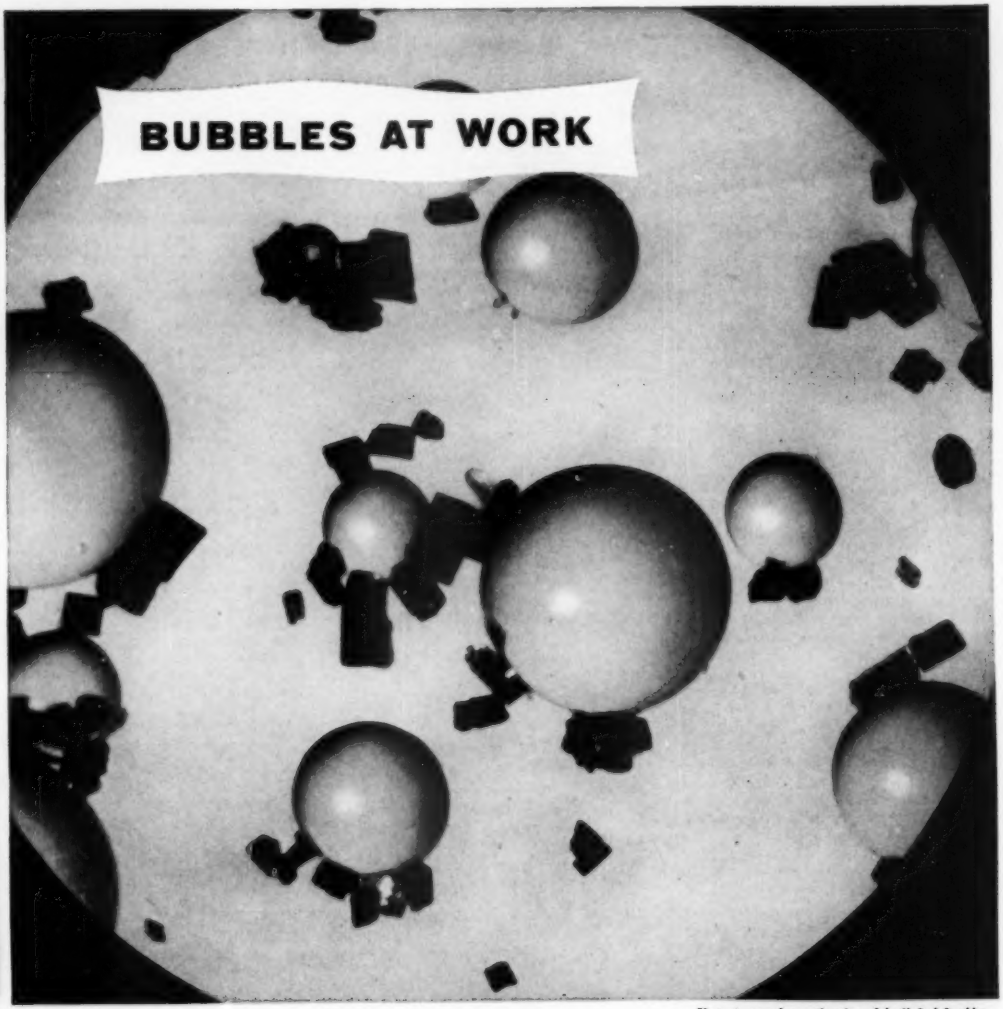
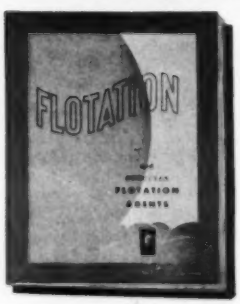


Photomicrograph, greatly enlarged, by H. Rush Spedden

To help step-up flotation recoveries at low cost, Hercules has developed a number of frothers and collectors. Yarmor® F Pine Oil has been a standard of quality among pine oil frothers since the early 1920's. RADA (Hercules' Rosin Amine D Acetate) is a siliceous mineral collector that has good solubility and is easy to handle. It is used in the commercial flotation of several nonmetallic ores. These and other Hercules products are described in a 16-page technical booklet, "Flotation and Hercules Flotation Agents." This booklet also contains many formulas useful in the operation and control of modern ore-dressing mills. Send for your copy.

HERCULES POWDER COMPANY 955 King St., Wilmington, Delaware



HERCULES Flotation Agents

NMS1-1

Carset Jackbits enable you to

INCREASE PRODUCTION 20% OR MORE

... without increasing your drilling crews!

Carset Jackbits *DRILL 50% FASTER* (or more)—maintain uniformly high drilling speed for the full depth of the hole. This means more work from less equipment and fewer men.

Carset Jackbits enable you to pull *LONGER ROUNDS*—because even after long usage they show negligible gauge wear.

Carset Jackbits practically *ELIMINATE BIT CHANGES*. Holes can be bottomed faster. The need for Nippers is greatly reduced.

Carset Jackbits require *LESS MAINTENANCE*—need only an occasional touch up on a hand or power grinder, thus releasing additional manpower for productive work.

These advantages of the Ingersoll-Rand Carset Jackbit add up to *MORE TONNAGE* of rock or ore broken per shift. Many users report increases up to 50%—with *no increase* in the drilling crew.

Ask for complete information on Ingersoll-Rand's longer-lasting, faster-drilling Carset Jackbits. Bulletin No. 4104.

CARSET JACKBIT

Ingersoll-Rand

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ROCK DRILLS • COMPRESSORS • AIR TOOLS • TURBO BLOWERS • CONDENSERS • CENTRIFUGAL PUMPS • DIESEL & GAS ENGINES

Mining Copper "UPSIDE-DOWN" in the ANDES MOUNTAINS

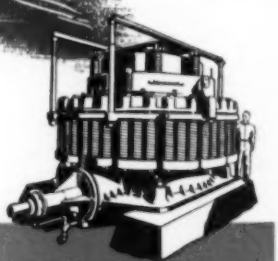
In the lofty Uspallata Pass of the famed Andes Mountains, almost 13,000 feet above sea level, stands the huge bronze *"Christ of the Andes"*, marking the boundary between Chile and Argentina.

THIS interesting view shows Sewell, the upper mining camp of El Teniente Mines of the Braden Copper Company . . . carved in the western slopes of the Chilean Andes, at an elevation of 7,000 feet.

El Teniente Mine is unique in that it is "upside down". The ore occurs high up on the mountain side and is dropped some 2,000 feet through chimneys in solid rock to an adit tunnel haulage way. Miners and supplies are hoisted, rather than lowered, to their working places.

The crushing plant at Sewell includes twelve *"SYMONS"* Cone Crushers which reduce all ore mined to less than 3/8" diameter for further treatment.

No matter where you travel in the Mining World . . . from the Andes Mountains to the Zambesi River country . . . you will find *"SYMONS"* Cone Crushers the outstanding choice among the world's leading producers of ores and industrial minerals.



"SYMONS" Cone Crushers . . . the machines that revolutionized crushing practice . . . are built in Standard, Short Head, and Intermediate types, with crushing heads from 22 inches to 7 feet in diameter—in capacities from 6 to 900 tons per hour.

NORDBERG MFG. CO., Milwaukee, Wisconsin

"SYMONS" . . . A NORDBERG TRADEMARK KNOWN THROUGHOUT THE WORLD

M252

"SYMONS" Primary Crushers

Grinding Mills

Mine Hoists

"SYMONS" Vibrating Bar Grizzlies and Screens

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MACHINERY FOR PROCESSING ORES and INDUSTRIAL MINERALS

NEW YORK • SAN FRANCISCO • SPOKANE • WASHINGTON • TORONTO
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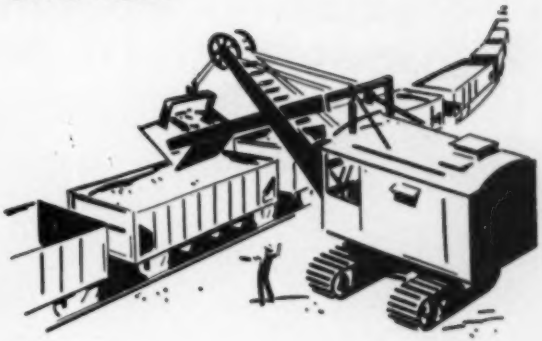
power-hungry shovels

need ANACONDA

BUTYL-INSULATED



SECURITYFLEX Cable

Butyl insulation gives Securityflex* Cable:
Higher dielectric strength; better electrical characteristics.
Greatly increased resistance to heat (rated at 80° C.)

Butyl insulation *plus* tough neoprene jacket gives Securityflex:
Outstanding protection against impact, crushing, twisting and abrasion.
Ability to withstand moisture, acids, oils, ozone, flame.

Its special "copper-cotton" shield eliminates failures due to chafing and makes splicing faster and easier.

Its patented rubber-cored ground wires resist kinking, give more contact with conductor shield and provide a cushioned construction that positively prevents ground wires from cutting insulation!

This means more safety, longer service, less maintenance, fewer power interruptions and hence more production at less cost.

Investigate the outstanding performance of Anaconda's Butyl-Insulated Securityflex Type SHD Cable. Let Anaconda's shovel-cable service specialists demonstrate it. Get in touch with your nearby Anaconda Sales Office or Anaconda Distributor. Anaconda Wire & Cable Company, 25 Broadway, New York 4, New York.

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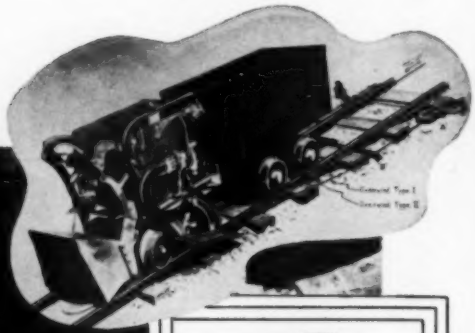
the right cable for the job

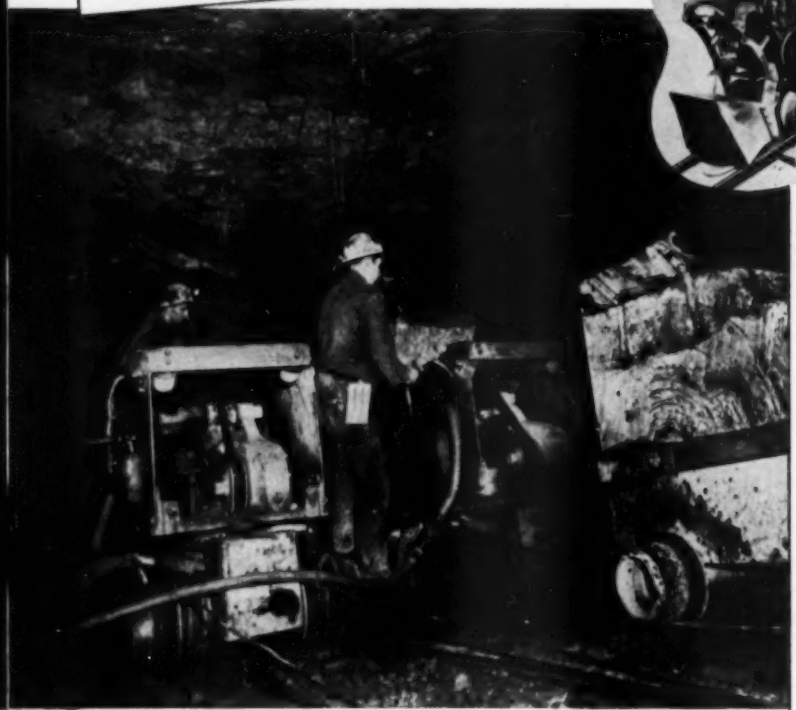
ANACONDA®

WIRE AND CABLE

A SUCCESSFUL INCLINE LOADING JOB OPHIR UNIT

Ophir Unit of the United States Smelting Refining and Mining Company, Ophir, Utah, 26° slope, 1450' length, size 8' x 12'





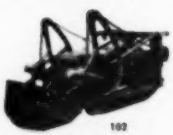
A 299

MODEL 12-B

MODEL 21

MODEL 40-H

MODEL 15



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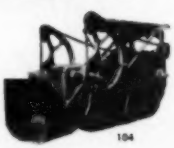

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Sinking incline shafts from the surface or from one level to another is a difficult undertaking for any crew.

Mining companies as well as contractors have found that using an Eimco "Slope-Loading" RockerShovel does speed-up the mucking cycle by 300% to 400% and have standardized on this type of equipment.

Slope Loaders work on slopes to 30° from horizontal and have the advantage of wide clean-up, fast digging and loading, with easy operation in all positions.

Eimco Slope Loaders can be easily converted to tunnel loading machines when the incline is completed.

Write for more information.

This is the 13th in a series of tunnel loading case histories. Write for the complete series.

EIMCO

THE EIMCO CORPORATION

The World's Largest Manufacturers of Underground Rock Loading Machines

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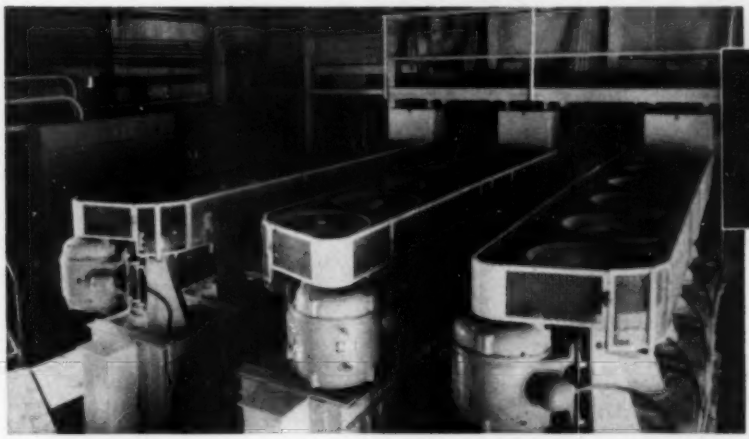
AGENTS IN ALL PRINCIPAL CITIES THROUGHOUT THE WORLD

You can't beat an Eimco!

ANNOUNCING! a New Metallurgical Tool
THE WEMCO ATTRITION MACHINE



Views of WEMCO Attrition Machines in operation.

Opening an extensive range of new mineral dressing possibilities, the field proven WEMCO Attrition Machine fits two important classes of metallurgical applications: (1) Treatments to make subsequent processing possible where other means have failed or proven too costly, and (2) Direct improvement of mineral products to meet market specifications.

APPLICATIONS

Treatment of Particle Surfaces

- Removal of oxidized coatings
- Elimination of slime coatings
- Removal of reagent coatings
- Surface polishing of particles

Liberation of Cemented Minerals

Ores or industrial minerals of this type may be separated, either the particles or the cementing material being recoverable for valuable mineral content.

PRINCIPLE OF OPERATION

By controlled turbulence of high density pulps, the WEMCO Attrition Machine thoroughly abrades mineral and ore particles. The imparted action is decidedly more efficient and complete than similar treatment previously attempted in grinding mills. Power consumption is greatly decreased, averaging 3½ to 7 kw. per ton of capacity. Maintenance and replacement costs are lowered to approximately 1 cent per ton of output.

PLANT OPERATIONS AND LABORATORY TESTING

Many months of actual plant operation and extensive laboratory programs have demonstrated the wide adaptability of the WEMCO Attrition Machine. Results obtained on a few of these ores are shown below:

- ***Tungsten ore*** — *Substantial improvement of flotation grade and recovery in the retreatment of former tailings.*
- ***Uranium ores*** — *Liberation of uranium minerals in the cementing material of sandstone.*
- ***Glass sand production*** — *Removal of iron oxide stain to meet market specifications.*
- ***Aggregate and sand production*** — *Disintegration of sand and clay cementing material from aggregate, saving both aggregate and sands for marketing.*
- ***Sulfide ores*** — *Removal of semi-oxidized coatings, making flotation separation possible.*
- ***Gold ores*** — *Greatly increased flotation recovery by removal of reagent and oxide coatings on former tailings.*

WRITE TODAY for further information pertaining to your problem. If desired, WEMCO's mineral testing laboratory is prepared to make attrition tests on samples of your ores and industrial minerals.

OTHER **WEMCO** PRODUCTS

Mobil-Mills • Coal Spirals • HMS Thickeners • HMS Pumps • Sand Pumps Cone Separators • Drum Separators • Fagergren Laboratory Units • Agitators Fagergren & Stelfenson Flotation Machines • Hydroseparators • S-H Classifiers HMS Laboratory Units • Dewatering Spirals • Thickeners • Conditioners • Densifiers

WEMCO

WESTERN MACHINERY COMPANY

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Triple reasons for specifying...

TRIPLE ALLOY STEELS *containing* NICKEL

1 PERFORMANCE—Strength and toughness, resistance to wear, fatigue or shock to meet a wide range of requirements, as dictated by design.

2 VERSATILITY — Ability to meet varied specification demands after suitable heat treatment.

3 ECONOMY—resulting from standard compositions precisely graded to match the engineers' needs.

Experience shows that triple-alloy steels containing Nickel are solving some mighty big problems in many industrial fields. They have established outstanding service records in some of the most exacting applications. The many standard compositions available make it possible to select *accurately*, and with economy, triple-alloy steels to fulfill the requirements of a great variety of applications.

We invite inquiries regarding the selection and uses of triple-alloy steels, containing Nickel.

THE INTERNATIONAL NICKEL COMPANY, INC. 67 Wall Street New York 5, N.Y.

The St. Lawrence Seaway and power project has received the support of the Canadian Parliament, with the House of Commons approving a bill that authorizes the Government to proceed with construction of the seaway, with or without U. S. cooperation.

Itogan Mining Co., third largest gold mine in the Philippines, reopened in December under the management of Marsman and Co. The mine was almost totally destroyed during the occupation.

The International Materials Conference committee on copper, lead, and zinc has recommended against stockpiling during the first quarter of 1952 because of the current demands for defense needs. The General Services Administration has told producers who have contracts calling for delivery of copper to the stockpile during the first quarter of 1952, that they do not need to make those deliveries.

Mack C. Lake, president of Orinoco Mining Co., United States Steel subsidiary, announced that a contract has been awarded to the Morrison-Knudsen de Venezuela for the construction of a 90-mile standard gage railroad and highway from Puerto Ordaz on the Orinoco River to the Cerro Bolivar mine. The contractor is an affiliate of the Morrison-Knudsen Co., Inc. of Boise, Idaho.

Steep Rock Iron Mines, Ltd. is continuing work to drain and remove lake-bottom-glacial debris from Steep Rock Lake to get at its 60 million-ton-iron-ore deposit. A contract was signed with Construction Aggregates Corp. for this reclamation project, and to accomplish this the Construction Aggregates has moved a 900-ton dredge into the lake, which lies 140 miles north of Duluth, Minn.

Colorado Fuel & Iron Corp. has announced that it has acquired all the assets of the E. & G. Brooke Iron Co. Brooke and a subsidiary operate a blast furnace in Pennsylvania and an iron ore mine in New Jersey.

Kennecott Copper Corp. will open a northwest exploration office in Spokane, Wash., to make studies of mining properties in the Metaline mining district of Washington and the Coeur D'Alene district of Idaho. L. B. Moon, formerly chief of the Minerals Division of the Bureau of Mines, will be in charge of this office. Mr. Moon reported Kennecott is interested in any type of metal deposit promising large scale production.

Leadridge Mining Co., a subsidiary of St. Joseph Lead Co., announced the execution of agreements covering the prospecting and development of uranium deposits in the Beaver Lodge Lake area in northwestern Saskatchewan. The exploration work is to be done in conjunction with the Amax Athabasca Uranium Mines, Ltd. and Aurora Uranium & Gold Mines, Ltd., who control the properties.

the hard way . . .

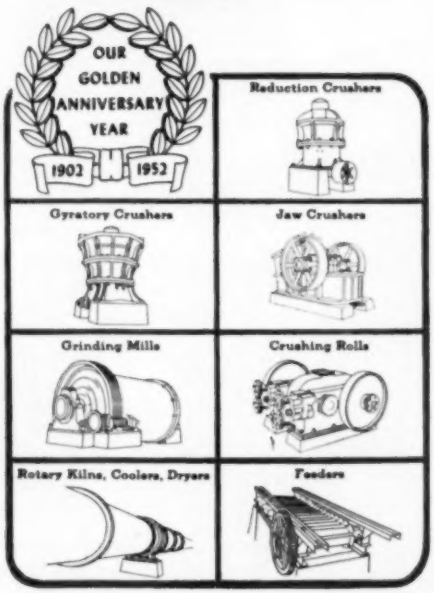
This old Mexican method of crushing ore applied the simple laws of gravity and leverage—excellent principles but inefficiently used in this case.

The Traylor TY Reduction Crusher is a perfect example of compact, simple design for efficient operation. For specifications and description, ask for Traylor Bulletin 6112.

THE MINING INDUSTRY passed through many interesting and unique phases before reaching its modern level of efficiency.

For 50 years, Traylor spearheaded its advancement by developing more efficient machinery for crushing ore. As processes and methods changed, Traylor took the lead in supplying new and improved equipment to fit each specialized job.

Mining men know that to solve new problems, there is no substitute for experience. Traylor has experience—half a century of it.



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ENGINEERING & MANUFACTURING CO.

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A TRAYLOR LEADS TO GREATER PROFITS

Bureau Charges Laxity in Coal Dust Accumulation in Illinois Mine Explosion

Faulty rock dusting of the New Orient Mine at West Frankfort, Ill. was declared to have been the primary cause of the extent of the blast that killed 119 men on December 21.

Walter Eadie, state director of mines and minerals, ascribed the explosion to the ignition of methane in a working place about a mile northwest of the shaft of the mine. The initiation of the combustion was either by a spark from electrical machinery or from men smoking in the mine. It was surmised that a train of empty cars stalled in a ventilation door, had caused sufficient disturbance in the ventilation system to permit accumulation of gases.

The Federal Bureau of Mines said that the Illinois explosion was caused by an electrical spark that touched off the clouds of gas present because of the faulty ventilation equipment.

The bureau report listed three conditions as primarily responsible: An inadequate ventilating system, operation of faulty electrical equipment and the presence of large accumulations of fine coal dust capable of exploding.

"This coal dust, principally along roadways, was not removed from the mine or rendered inert by the application of sufficient rock dust," the report stated.

Investigations showed that an even more disastrous blast was averted because the explosion eventually reached areas where it could expand into open workings and where enough rock dust had been applied to retard it.

Mexico To Develop Iron Ore Deposits

The Mexican Government announced it would try to develop important Pacific Coast iron deposits with its own money.

Antonio Martinez Baez, minister of national economy, said the Navy Department would build a new port on the Pacific coast about half way between Acapulco and Manzanillo. The Government will build a railroad to carry the iron ore to the new port.

Martinez Baez said a new steel plant will be built somewhere along the Pacific coast.

The deposits here were formerly owned by the Bethlehem Steel Co., but were expropriated. Mexico has been seeking some 160 million dollars in foreign capital for the exploitation of the mines, whose reserves are estimated at 120 million tons.

Two Nations Ready For Tin Discussion

An Indonesian Government mission is here to discuss a possible tin purchase agreement, an Embassy spokesman stated.

Administrator W. Stuart Symington said he expects that Reconstruction Finance Corp. officials will meet with the Indonesian group, which will number about five.

Symington, who is leaving RFC, denied reports of an imminent shutdown of the nation's only tin smelter at Texas City, Tex. He said RFC's stocks of ore and concentrates are low but haven't yet reached the vanishing point, despite the almost complete withdrawal of the United States from the world market for the past few months.

Emerging from a conference with State Department officials, Bolivian Ambassador Ricardo Vargas said he hopes negotiations can soon be resumed to sell Bolivian tin to the United States.

He said Bolivia's demand for $1.50 a lb for its tin was not mentioned and he refused to say whether Bolivia is still insisting on that price. He also refused comment on a steel-for-tin deal made with Britain. The United States will buy tin from Malaya.

Symington told newsmen that he is "sure that nobody is going to pay anything like the price the Bolivians have been asking." RFC has offered Bolivia about $1.12. Negotiations between RFC and Bolivia broke off last November on the price issue.

Wemco Announces New Attrition Machine

The availability of the new attrition machine has been announced by Ralph B. Utt, general manager of Western Machinery Co. Based on field operations, and extensive laboratory investigations, the new unit has wide application in several industries, including: ore dressing, coal preparation, sand and gravel beneficiation, chemical and other processing industries.

The application of attritioning action by the new machine produces two broad effects on the material treated. For the treatment of mineral particle surfaces, the unit has proved effective in the removal of slime, oxidized and reagent coatings undesirable in further processing; the cleansing and polishing action is highly beneficial to the treatment of minerals involving the meeting of marketing specifications. In the treatment of ores and industrial minerals wherein particles are held together with a cementing material, the attrition machine may be applied to liberation of the particles from the cementing material; this action has

Operating principles of the new attrition machine are based on the controlled turbulence of high density pulps. Shown is a six-cell unit.

specifically been applied to sandstones where the sand grains were cemented by a material containing clay and finely divided minerals.

The operating principle of the new product is based on the controlled turbulence of high density pulps. The resultant action simulates the rubbing of particle against particle. The optimum density is of the utmost importance and will depend on the problem at hand. To date several problems have been encountered where best results were obtained at 83 pct solids.

The machine is made up of two, four or six octagonal shaped cells operating in series, and mounted on a common base. Each cell includes a motor driven vertical impeller shaft on which are mounted three, 6-bladed impellers. Pitch of the impellers in each cell is alternated so that in Cell 1, the top impeller throws the pulp downward. Rotation is clockwise, and the pulp passes from Cell 1 to Cell 2 through an opening near the bottom of the partition between cells. In Cell 2 the impeller pitches and direction of rotation is the opposite to Cell 1 and the pulp flow to Cell 3 is through an opening near the top of the partition between cells.

Kennametal Announces Tungsten Purchase Program

A purchase program for tungsten concentrates which are below the grade required for the Government stockpile has recently been announced by the Kennametal, Inc. Concentrates, middlings and ores ranging in grade from 20 to 60 pct WO_3 will be purchased at prices to be negotiated in each case, depending upon location, amount and impurities. Scheelite, wolframite, hubnerite, ferberite and cuproscheelite will all be considered.

The company reports that special refinery processes enable utilization of the lower grade material, thus minimizing penalties.

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U·S·S LORAIN ROLLED PLATE LININGS AND U·S·S GRINDING BALLS

USS

UNITED STATES STEEL

Mather Mine Sets Production Record

The Mather Mine broke all existing iron ore production records on the Marquette Range last year. The largest underground iron mine in North America yielded 1,635,256 tons in 1951, or 335,175 tons better than the previous record established in 1950 by the same mine.

The mine, which has one shaft in Ishpeming and another in nearby Negaunee, Mich., is operated by the Cleveland-Cliffs Iron Co. for the Negaunee Mine Co.

Mineral Output Up 10 Pct in 1951

Spurred by defense demands, the U. S. mineral output has risen almost 10 pct over the preceding year. The Bureau of Mines reported this in a year-end statement on the mineral industry. Production of metals such as iron ore, copper, zinc and lead was up about 9 pct, while output of nonmetallics, coal, oil, cement, stone, and sulphur rose 10 pct on the average.

Iron ore was up to 126 million tons last year from 109 million tons in 1950 to meet the requirements of the record-breaking steel production, which topped the 100 million mark for the first time in history. Copper rose to 950,000 tons in 1951 against 909,000 tons in 1950. Copper shortages will continue, with imports lagging as a result of differences in U. S. price ceiling and prices in the international market. Zinc production was 785,000 tons in 1951, an increase of 10 pct, but lead production dropped. Lead and zinc output is expected to increase considerably in 1952 as the result of government exploration grants and production expansion aids.

There was a 10 pct boost in such items as cement, sand and gravel, stone, sulphur, and other raw materials used in the construction and chemical industries.

Recovery of Vanadium From Phosphate Rock

Possibility of economic recovery of vanadium from western phosphate rock through a combination of two distinct processes was disclosed when the Bureau of Mines released the results of extensive tests conducted in Oregon and Idaho to extract the scarce metal. The report on the processes for recovering vanadium from western phosphates contains technical descriptions of the smelting, oxidizing, and leaching tests and offers statistical data of the various results obtained.

A combination of beneficiating smelting and roast-leach processes described in the report may make it economically feasible to recover not only vanadium but phosphorus as well from a vast tonnage of western phosphate rock.

INCO Completes Pipelines to Pump Concentrate

A 7½-mile pipeline has been completed by the International Nickel Co. of Canada, Ltd., through which the bulk concentrate from 3,650,000 tons of nickel-copper ore is being pumped annually from its new Creighton concentrator to its reduction plants at Copper Cliff.

In making the announcement R. L. Beattie, Vice President and General Manager, said: "The pipeline reduces the time required to transform nickel ore into refined nickel. Further, the economies resulting from pipeline transportation, together with other economies, have made possible the working of lower-grade Creighton ore which is now contributing to the availability of nickel for the defense production needs of the free world."

Part of Inco's $130 million program of underground mine expansion, the pipeline artery has been integrated into an elaborate pipeline system which also carries tailing, or waste material, from both Creighton and Copper Cliff to a disposal area midway between the two plants.

The system has 12 miles of trestle, at some points 65 ft high to assure a slope to and from each of the five relay pumping stations so that the concentrate lines will be self-draining in case of power difficulties. All told, 3 million board feet of lumber and 40 miles of wooden pipe were used.

When milling 10,000 tons of nickel-copper ore per day at Creighton, approximately 1800 tons of concentrate and 8200 tons of tailing are produced. Water added to the concentrate makes a pulp which flows through the pipeline at the rate of 800 gallons per min. The tailing pulp flows at the rate of 2500 gpm.

Despite the rigorous northern winter weather, the complete pumping system has been designed for trouble-free operation. Several times the temperature has dropped to 30 degrees below zero without operating difficulties.

View of tailing disposal area with International Nickel's Copper Cliff, Ont. smelter stacks in the skyline. In the foreground is the end of Creighton tailing line; veering off to the left, Creighton concentrate line carries on toward Copper Cliff.

CONVEYING OF CREIGHTON CONCENTRATE AND COPPER CLIFF AND CREIGHTON TAILINGS

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There is no such thing as bit dressing when your test drilling is done with Hawthorne "Blue Demon" bits.

Bit service by Hawthorne comes in sturdy, plainly marked wooden boxes, convenient for handling and storing. Factory controlled high quality accompanies every box.

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½"	0.840	0.622	540	0.103	400 ft. coils
¾"	1.050	0.824	350	0.140	400 ft. coils
1"	1.310	1.070	200	0.181	300 ft. coils
1¼"	1.660	1.380	200	0.267	300 ft. coils
1½"	1.900	1.610	200	0.320	250 ft. coils
2"	2.378	2.070	170	0.445	200 ft. coils
2½"	2.875	2.469	170	0.680	200 ft. coils
3"	3.504	3.070	165	0.910	100 ft. coils
4"	4.504	4.030	150	1.250	25 ft. str.
6"	6.630	6.070	115	2.230	25 ft. str.

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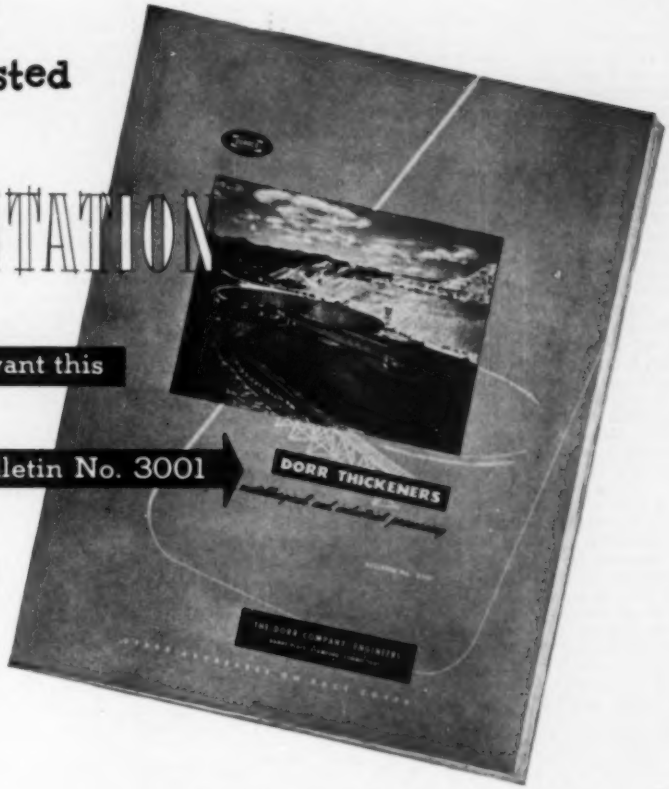

Bulletin #3001, "Dorr Thickeners for chemical, metallurgical and industrial processing" has just come off the press. Containing 28 pages of descriptions, drawings and photographs, it covers the comprehensive line of Dorr Thickeners briefly and factually. If you're concerned with thickening problems and the equipment with which to solve them, you'll find it helpful. Write for your free copy today.

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DESPITE strikes, domestic production of copper and zinc in 1951 rose about 3 pct and 10 pct, respectively. Lead output fell only about 7 pct. Primary refined, including processed scrap and imported concentrates, was somewhat higher for zinc, and slightly lower for copper and lead. Prospects are for moderately larger mine and refined production in 1952 according to Standard & Poor's analysis of nonferrous metals.

The survey goes on to report domestic copper prices averaged 14 pct higher in 1951, lead prices 30 pct higher, and zinc prices 32 pct higher. The 2¢ rise in zinc and lead ceilings in October will lift the average price in 1952 over 8 pct, assuming no further price change. Currently, OPS appears opposed to raising the 24½¢ domestic copper ceiling to the 27½¢ maximum on imported metal. The steep premiums in world markets are likely to be reduced in 1952.

Sales in 1951 were at new peaks. A further moderate rise is indicated for 1952.

Earnings of the industry were at a new high in 1951. The increase for companies covered in the survey was perhaps 25 pct, despite a tax rate of about 53 pct, against about 40 pct in 1950. Relatively maintained to moderately higher earnings are currently indicated for 1952. About two thirds of the companies covered in the survey raised dividends, including extras, in 1951. In general, maintained payments appear probable in 1952.

AMERICAN capital investments abroad have been increasing since the close of World War II; reaching a peak of $1.2 billion in 1950. In 1951, foreign investments declined from the record year by something less than 50 pct, or $583 million dollars for nine months of 1951. This reversal of a rising tide of foreign investment of American capital is probably due to the Korean war and disturbed conditions throughout the world of which the Iranian seizure of the British oil interests in that country is a prime example.

United States petroleum, manufacturing, and mining interests dominated the foreign investment field which increased from $8.8 billion at the end of 1946 to over $14 billion by the end of September 1951.

Only investments in Canada continued to increase in 1951 because of expansion of raw material sources there (petroleum, copper, iron, asbestos, nickel, titanium, etc.) expansion of United States manufacturing facilities, greater security in Canadian investment, and speculative possibilities. Investments in Latin America had been increasing except for the last two years when they began to decline. Cutting off Iranian oil to world markets may put pressure on American petroleum interests abroad for future expansion to replace this source of oil.

WHAT is believed to be the first application of reflection seismography to ore exploration was made last fall by a Stanford Research Institute crew operating in Minnesota. By applying the Poulter Seismic Method and special instrumentation to the problem of determining the depth of glacial debris overlying iron formation, the crew was able to cover a 70-mile line quickly and economically by comparison with drilling methods.

The method may be used for a rough, rapid reconnaissance with little control. It may also be used to carry data between widely spaced drill holes, or, with good control, to make a detailed subsurface map of an area with precision. Many potential applications to other types of mining problems as well as to engineering and ground-water studies are foreseen.

REPORTS from London by Associated Press are that Britain is recruiting jobless Italians to help meet a manpower shortage in British coal mines. The story says that over 1000 Italians already have arrived in Britain for work in the coal mines, and more are coming. The National Coal Board, which operates England's socialized coal industry, says it wants to bring in many more. The need for miners is such that it has no special quota.

Bituminous Coal Institute takes this development as an interesting sequel to nationalization of the coal industry. When government operation of the mines was proposed, the project was hailed by its proponents as a worker's utopia. But in practice, socialization turned out to be something quite different and quite unattractive. The miners found they had traded a boss with whom they could bargain for a remote, tangled authority of bureaucratic red tape—a distant dictator who seemed incapable of righting even petty grievances in personnel relations and working conditions.

The result has been a rising rate of absenteeism and job quitting, which the Coal Board has admitted to be a major problem. Now, Britain is importing jobless Italians to try to get more of the coal so urgently needed.

And while socialism fails to produce, the gap is being filled by the United States coal industry in which freedom and competitive private enterprise keep things healthy and humming.

CABINET rank for the mining industry was the essence of a proposal recently made by Representative Walter S. Baring (Dem., Nev.), who introduced a bill, HR 5964, designed to establish a Minerals Department of the government and add a new member to the President's Cabinet. This development followed his expressed dissatisfaction with the "ineffectiveness of the present defense minerals setup, and the inability of the Federal Government program to function."

The legislation is a drastic move toward separating the entire minerals division from the Department of the Interior. This would give the mineral industry a voice at the top level without being lumped with Indian affairs, irrigation, reclamation, and public power.

SCRAP enough to keep the steelmaking furnaces of the nation running has been the objective of a nation-wide campaign to which all industry has responded admirably. As additional steel capacity comes in, more scrap will be needed. Exuding confidence, Stanley M. Kaplan president, Institute of Scrap Iron & Steel, Inc., addressing the 24th annual convention of the Institute, said in part: "Just one year ago there were those skeptical pencil-pushing statisticians who openly predicted that the scrap industry could not possibly furnish over 31 million gross tons of scrap. The need in 1951 proved to be 34 million gross tons—and that, my friends, was the approximate quantity delivered.

"Now, gentlemen, as you well know, the entire steel industry is expanding at a magnificent pace and from all indications the demand for purchase scrap from ourselves in the year 1952 will approximate 36 to 38 million tons.

"The same prophets of gloom of last year's standing are once again shouting it can't be done! It's impossible! Steel operations will have to be cut drastically!

"To these, gentlemen, we shall reply, 'hog wash'!"

Not for an instant did Mr. Kaplan minimize the difficulties of meeting the 1952 goal; but he emphasized that it could be met by hard work and ingenuity.

FAILURE of the Tungsten-Molybdenum Committee of the International Materials Conference to agree on a purchase price for tungsten was the cause of the breakdown of the proposed program for the long-term

allocation of the metal (*Mining Engineering*, January, 1952, p. 29), it was confirmed.

The consuming countries are said to have stood firm on a price of $60 while the producing countries held out for $65.

The IMC announced that "the committee found that it was not possible to make further progress on the proposed long-term agreement for tungsten. It was felt that for the time being, at any rate, no useful purpose would be served by reopening discussion on this subject."

The committee will continue to make short-term allocations of tungsten as well as molybdenum. Inquiries today indicated the government's purchase price will be $60 for foreign offerings of tungsten.

INCREASING demand for silver and silver products for industrial use offset to some extent the sharp dropping off of the requirements for sterling by the silverware manufacturers in 1951, it was announced in the *Review of the Silver Market for 1951* issued by Handy & Harman, fabricators of precious metals.

Approximately 110 million oz of silver were consumed in the arts and industries in the United States during 1951, a drop of only 10 million oz below 1950. This compares favorably with other postwar years, according to the report.

Considering the inflationary pressures exerted in general on prices in the United States during the early part of 1951, the price of silver in New York showed remarkable stability. The outlook for the foreseeable future points to a maintenance of price stability for silver, according to the report. Fluctuations in the price of silver will continue to be relatively narrow, with a ceiling provided by the availability of production now sold to the Mint at 90.41 cents, and a support provided by Mexico's probable need for at least a major portion of its own production in the coming months.

The price increases generated in most world commodity markets by the Korean situation were more extreme than the relatively moderate rise in the price of the white metal. At no time were buyers faced with the acute supply problem which existed in other nonferrous metals.

Should there be an increase in the coming months in the present relatively low demand, which might result in stepped-up defense spending and the use of silver as a substitute for scarce metals, there is no apparent reason to fear that adequate supplies will not be available. The Treasury's selling price of 90.91¢ per oz .999 fine is presumably still effective at least for some portion of its unobligated stocks. With regard to Treasury stocks the review points out that because of coinage requirements the so-called free silver account declined from 159,900,000 oz at December 31, 1950 to 127 million oz at the close of 1951, a drop of 32,900,000 oz.

Cuban supplies would be available on the basis of a published rate of 90.16¢, assuming there is no change in the decision to sell at the current market. It is not unlikely that other stocks might come in the market in the absence of an incentive to hold for a higher price. One such possible source is Japan, where a substantial stock of metal is being held pending official decision. The quantity involved has been reported variously at 50 to 60 million oz.

Silver production in the Western Hemisphere during 1951 declined slightly from figures reported for 1950. The total for the year is estimated at 130,700,000 oz, about 7 pct below 1950.

Mexico showed the sharpest drop. That country's production probably did not exceed 41 million oz, compared with 49,100,000 oz reported in 1950. Production in the United States was also lower, being estimated at 40 million oz compared with 42,100,000 oz previously.

The silver content of total imports of bullion, unrefined material, and coin amounted to 114 million oz. Total exports amounted to 8,300,000 oz.

IN reviewing the 1951 lead picture, Andrew Fletcher, president of the St. Joseph Lead Co., pointed out that while domestic mining and smelting industries were operating under a price ceiling of 17¢ per lb of lead, world competitors were enjoying the European price of at least 21¢. U. S. supplies became tight when foreign production which would normally have come here, went to the European market. Only a few U. S. consumers were in a position to import at above ceiling prices.

In October 1951, the ceiling price was raised 2¢ per lb to 19¢ and consumers were regulated against paying more than the ceiling price, plus any duty, for their lead imports.

The supply of lead available for domestic consumers, Mr. Fletcher points out, comes from mine production, imports, and scrap.

Domestic mine production for 1951 is estimated at 390,000 tons, compared with 430,000 tons in 1950, a drop of 10 pct owing to strikes, and the difficulty of procuring an adequate supply of mine labor.

Imports of lead declined sharply and totaled, in all forms, about 225,000 tons for 1951, as against 542,000 tons in 1950, a drop of over 50 pct. This sharp decline is a good illustration of the effect of unrealistic ceilings.

The reclamation of lead from scrap improved slightly, and for 1951 is estimated at 500,000 tons, compared with 482,000 tons in 1950. In point of relative size, scrap lead has become the most important single source of lead in the United States.

In 1951 these three sources totaled 1,130,000 tons which compared to last year's consumption of 1,230,000 tons. The 1951 demand was increased by scare buying, but the deficit between actual consumption and supply was not great. In fact, only a relatively modest increase from imports, or a small increase in estimated domestic production, would result in a balance. There is some indication that the sharp demand in Europe for lead, and the desire to convert currencies into commodities, are subsiding, as indicated by the recent drop in the Mexican lead price, Mr. Fletcher said.

There was no military stockpiling of lead during the year, except from some foreign sources. In November, the government authorized the release of 30,000 tons from the lead stockpile to ease the shortage.

Mr. Fletcher takes the position that "Although lead is an indispensable metal from a military standpoint, the quantity needed is comparatively small and does not warrant the control of the entire lead economy. Nor is lead any appreciable factor in the cost of living. It is difficult to understand how our country has been helped by governmental control of lead, especially when the defense effort has not, and will not suffer for want of a single pound of lead. It is well to remember that mining is characterized by a high degree of business risk, that increased production involves long-range planning, and that it is especially important to see that the taxes imposed upon an industry with wasting assets do not discourage the development of mineral resources. At the year-end the government is exhorting producers for greater output, and devising expedients such as price floors, loans, outright subsidies and curtailment of uses, but to date has been unwilling to return to the only practical remedy for curing the shortage—a free market."

Sulphur

Thousands of tons mined daily, but where does it all go?

LOOK AROUND YOU and let your glance fall on any object. The chances are 1000 to 1 that sulphur played an important role in its manufacture, either as a component part of the finished product or as a processing element.

Take, for example, the very magazine you are reading. If it's average size it weighs about 1 pound. Made largely of sulphite pulp it required about 0.1 pounds of sulphur in its manufacture.

Multiply this 0.1 pounds of sulphur by the thousands of magazines turned out every day and you'll get some idea of the tremendous tonnage of sulphur required for this *single* division of industry . . . the sulphite pulp manufacture.

Sulphur has long been called One of the Four Pillars of Industry. Today's need emphasizes this fact more than ever. Sulphur producers are making every effort to get maximum production from existing mines and to develop new sources of sulphur as quickly as possible.

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MINING ENGINEERING

EDITORIAL

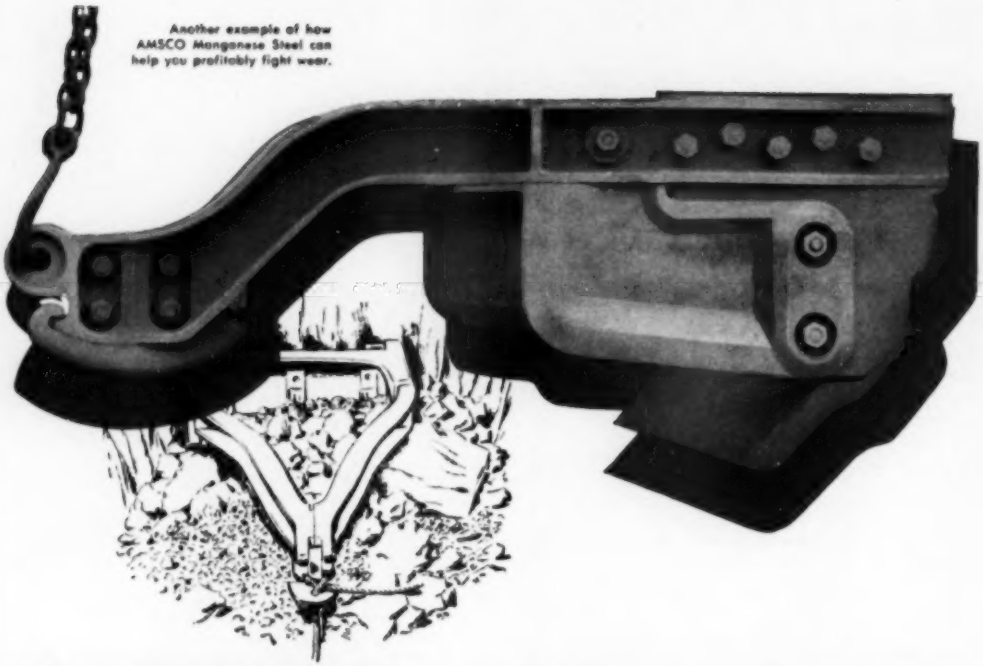
NOTHIN' DOWN

IN the western mines, the boss, engineer, geologist, or nipper in making rounds have a password which usually guarantees safe entrance to a working place from below the working miner. Most men won't climb a raise or enter a stope from below where a miner is working until they have shouted "nothin' down" and heard those words shouted back by the miners above. "Nothin' down" is a safety pledge as necessary and as binding as the truce flag to the soldier. It implies mutual confidence that work will be suspended until the person below has come abreast of the workers; and also confidence that the miner who replies "nothin' down" is reasonably sure the place is safe to enter. Like truce flags which are not infallible, so is this password subject to human errors or unexpected falls of rock, tools, or timber. Everyone knows these unavoidable hazards, but what is important to the exposed man is that in that precise moment of time when he has heard the reassurance of "nothin' down," he knows that *safety* is uppermost in the minds of the men above him.

With such assurance we would go anywhere and so would most mining men. If that period of safety consciousness, procured by the utterance of two words, could be multiplied to equal the hours in the working day, there would not be any accidents but those by "the act of God." It is the aim of every safety program to make safety as natural as breathing. That is the reason for the posters, the conferences, instruction periods, safety engineers, and the inspections. But none of these are as effective as one accident, which keeps men on their toes for weeks to come. This is not the price we want to pay for safety consciousness.

This Annual Review number of *Mining Engineering* is full of talk about production. *Production* for defense, *production* for profit. In this tremendous surge of industrial might to make this nation and our very families safe from the predatory forces abroad in the world today; let us not lose sight of the fact that the safety of our manpower is more precious than any commodity. Production without safety is detrimental to the national interest, to that of the company, and to the individual.

If the words "nothin' down" can give us the best human guarantee of safety, for however brief a time, let us adopt them at least in principle as our slogan in 1952. Production for preservation in '52 — but NOTHIN' DOWN!



Another example of how AMSCO Manganese Steel can help you profitably fight wear.

This SCRAPER cut maintenance costs 20%!

How AMSCO Manganese Steel proved tougher than a tough mining problem

One of the toughest mining operations you'll find anywhere—tough from the standpoint of how it punishes equipment—is scraping heavy, corrosive pyrite ore. For example, a California mine has a deposit of 98% pure pyrite—with a specific gravity of 4.8. Impacts and abrasion caused by this ore were making short work of the scrapers previously used . . . on the average they needed major repairs over 4 times per year.

Several years ago two scrapers of the type shown above, which are sold exclusively by Joy Manufacturing Co., were put in service. They were made entirely of AMSCO Manganese Steel, and since then they've mined *over 220,000 tons of pyrite ore — and they're still in excellent condition!* These scrapers are repaired only once a year; simple repairs involving relipping and hardfacing of wearing surfaces.

Obviously, not all mining or excavating operations are as equipment-punishing as this one . . . *but the moral is clear . . .*

WHEREVER YOU MEET A PROBLEM OF WEAR CAUSED BY IMPACT AND/OR ABRASION . . .

. . . find out about longer-lasting, dollar-saving Manganese Steel made by AMSCO . . . world's largest producer of Manganese Steel castings for all industry.

AMSCO controls impact and abrasive wear in 5 basic industrial operations:

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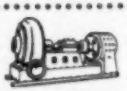

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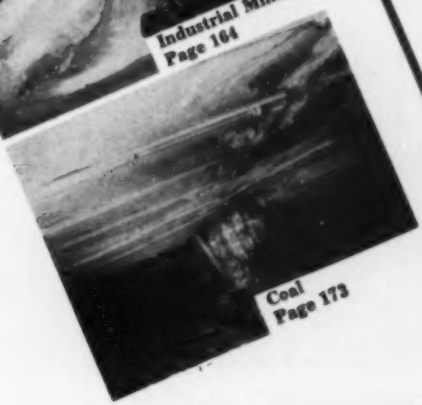

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Mining Geology

— — comes into its own as expanded minerals program takes hold and now must develop basic geologic principles of ore-forming processes.

by Olaf N. Rove

YEAR 1951 has been bright for the mining geologist. He has *arrived* after struggling for a generation or two to sell his wares through service to the operator, the mine superintendent, and the manager. But as he establishes himself on the operating front, he is faced with even greater challenges; namely, the development of basic geologic principles governing ore-forming processes and the occurrence and distribution of mineral deposits. These principles are needed to guide his ever-widening search into new areas. He must now stimulate the interest, confidence, and imagination of the mining executive and layman in fostering the research essential to expand rapidly the basic science of geology and its more specific applications to the mining industry. The hallowed time-tested tools of the prospector and the industry are no longer adequate. New basic data, principles, and ideas are needed to guide industry's exploration.

The entry of Government into exploration, by lending money to prospectors and operating companies to partly finance exploration, is one of the major events of the year. This was one of the activities for which the Defense Minerals Administration was established in the Department of the Interior. DMA was staffed largely with men from industry, but the Bureau of Mines and the Geological Survey have acted as its technical advisors and have provided its field staff. Since the start of this work in May 1951 to November 19, 1951, the DMA has approved 208 exploration projects while denying 318 others. The contracts involve about eleven million dollars worth of exploration, of which Government's share is about sixty percent. A few contractors have already made discoveries and are into production to repay their loans; others have completed their projects without making a discovery.

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In November, the DMA was split into two successor units. The Defense Minerals Exploration Administration was set up in the Interior Department to carry out the exploration program. The Defense Materials Procurement Agency was organized as a separate agency to carry out the other functions of the former DMA, as well as general strategic materials procurement.

The strategic materials group of the Economic Cooperation Administration was transferred to DMPA in order to centralize the procurement from foreign sources into one agency, although the authority and scope of activities of this group have not been announced as of the middle of December.

The DMA-DMEA-DMPA programs are making large demands upon the technical manpower of the Geological Survey and Bureau of Mines. It is still too early to evaluate with confidence the productiveness of this diversion so far as the immediate and long-range effects are concerned. Many of the individuals associated with these programs, as well as others in the industry, are convinced that from a long-range national viewpoint, the regular programs of both the Survey and the Bureau equal or even exceed in importance the current emergency mineral activities of these two agencies.

Uranium

Uranium continued to be the glamour-girl metal of the mineral industry, and at the request of the Atomic Energy Commission uranium and thorium were included in the DMA exploration program. Industry's intensive prospecting and mining activities in 1950 were further expanded early in 1951 when the Atomic Energy Commission announced an increased price schedule and a new bonus payment

plan to stimulate domestic exploration and production. Perhaps the most important new development took place in the Grants area of New Mexico where Santa Fe, Anaconda, and a number of small operators have extended reserves in the Todilto limestone and are exploiting new discoveries in the Brushy Basin member of the Morrison formation. New discoveries in the Lukachukai Mountains of northeastern Arizona are encouraging.

Marysvale, Utah, diamond-drill exploration has reached the stage where the companies are contemplating plans for important production. Colorado Front Range interest focuses on the Old Quartz Hill area, on the Lawson district, and on the Copper King property north of Fort Collins.

Airborne Geiger counter and scintillometer were used more extensively than before. A portable magnetometer survey in the Marysvale area has helped in exploration for pitchblende.

The AEC has instituted a program of training the Navajos in the techniques of uranium prospecting with the understanding that any ore found on the Reservation can be claimed by the finder. Three Navajos have already located claims and started development, and four others have found ore in inaccessible areas that must await road building.

Several phosphate companies have announced that they expect to start recovering by-product uranium from Florida phosphate operations in the near future.

Monazite production in the United States is experiencing a revival as a principal by-product of gold placer operations in Idaho. Considerable interest is also being shown in the southern Appalachian stream gravels and Coastal Plain dune and beach sand deposits.

In Canada, economic deposits of uranium were discovered at Eldorado Mining Co.'s Ace and Fay properties in the Beaverlodge Lake area, in Saskatchewan. As a result, several large companies are exploring properties and concessions in the area by surface diamond drilling and underground work.

Iron

Exploration of anomalies discovered by airborne magnetometer surveys near Reading, Pa., and Marmora, Ont., has resulted in two important discoveries of magnetite ore. The demand for brown iron ore at Birmingham has contributed to the discovery of new brown ores in central Mississippi and near Madisonville, Tenn.

Iron ore companies in the Lake Superior region have greatly expanded geologic staffs, and are actively testing new structures. Pickands Mather & Co. and Inland Steel Co. are testing parts of the Steep Rock Lake area. Jones & Laughlin Ore Co. and Algoma Steel Corp. are actively exploring the Michipicoten district.

Manganese

Low-grade manganese ore at Batesville, Ark., has been intensively explored by West Mooreland Steel Co. with DMA assistance. Production is expected in 1952. Taylor-Knapp Mining Co. plans to operate the Ladd mine near Livermore, Calif., to produce battery-grade ore. Minor manganese exploration is going on in Butte and Phillipsburg, Mont.

Chrome-Nickel

Although there are many rumors of large discoveries of high-grade metallurgical chrome ore in northern California and southern Oregon, facts to support such rumors are difficult to nail down. Without doubt, however, prospecting has been greatly stimulated by higher prices and by the Grants Pass, Ore., purchase depot.

The M. A. Hanna Co. is winding up its program of bulldozer trenching and churn drilling at the Riddle nickel deposit in Oregon. Development will hinge upon the outcome of metallurgical testing now in progress.

Falconbridge Nickel Mines Ltd. successful exploration by surface diamond drilling has led to underground development at their Hardy deposit, north of Sudbury. Falconbridge has discovered a new orebody 2½ miles northeast of the Hardy mine at depths ranging from 1600 to 3500 ft. The ore area underlies a small lake, and diamond drilling was done from the frozen lake and from barges. The ore occurs in a "grey granite" breccia in the footwall of a fault. Falconbridge has done a lot of experimental close-grid aerial magnetometer surveying, and also surface electromagnetic surveying; the McPhar Engineering Co. is now developing the latter technique to use in diamond-drill holes.

In Manitoba, the new Lynn Lake copper-nickel property of Sherritt Gordon is being developed. There is much nickel prospecting in the Conora district along the Ontario boundary. Inco's prospecting of the Ferguson River concession in Northwest Territories is reported not to have been successful.

Tungsten

Spurred by a Government-guaranteed price of $63 per unit of WO, for a five-year period, tungsten prospectors and miners are very active. The Hamme mine in North Carolina is expanding production and pushing development on the 700-ft level. Small operators are actively exploring and exploiting small but rich tungsten properties in San Diego County, the Mojave area, and the eastern and western slopes of the southern Sierra Nevada. Pine Creek, Tungstar, and Atolia are all booming.

At the Ima mine in eastern Idaho, two new tungsten veins have been found in essentially virgin ground, and the southern extension of the Ima vein system has been located with DMA aid. At the Yel-

Airborne geophysical surveys, formerly a curiosity, are becoming standard procedure. The magnetometer, shown below as viewed from the plane, was the forerunner to airborne Geiger counter and scintillometer methods.

low Pine mine at Stibnite, Idaho, some scheelite has been won from antimony-gold ores and from placer gravel. At the Emerald mine, Salmo, B. C., exploration has found a major scheelite orebody below the zinc ore, which will be brought into production in 1952.

Columbium

Two important discoveries of columbium have been made during the past year. Gordon and Murata found that the Arkansas bauxite ores contain approximately a pound of columbium per ton of bauxite. At Sukulu in Uganda, Africa, a pyrochlore-bearing residual soil derived from a large igneous carbonate-plug complex looks like a promising source of columbium.

Cobalt

St. Louis Smelting & Refining Co. has obtained DMA assistance to explore for colbaltiferous lead ores at Fredericktown, Mo. Improved silver and cobalt prices are stimulating activity at Cobalt, Ont. Calera Mining Co. has found some new cobalt-bearing shear zones at its mine at Salmon, Idaho; production from the main mine will start in 1952.

Lead and Zinc

American Zinc Co. of Tennessee has announced the discovery of ore equivalent to a million tons of sixty percent zinc concentrates in the Jefferson City district of Tennessee as a result of exploring structure. New Jersey Zinc is exploring near-by.

St. Joseph Lead Co. plans to develop its new disseminated lead orebody in Washington County, Mo. Moreover, it is continuing exploration over a large area that is considered favorable. Exploration in the Upper Mississippi Valley area of southern Wisconsin, northern Illinois, and eastern Iowa is active.

The Glidden Co.'s Bully Hill zinc mine northeast of Redding, Calif., is being reopened, and explored by diamond drilling.

Exploration in the Coeur d'Alene district still tends to push out laterally and in depth from known producing areas. In the Mullan area, the Atlas Mining Co. has been joined by Hecla Mining Co., New Jersey Zinc Co. and Newmont Mining Co. to sink the Atlas shaft to 2400 ft, from which point extensive exploration will be conducted. This work, in the eastward extension of the Silver Belt south of the Osborn fault, will test the importance of surface showings of chloritic and sericitic alterations that contain carbonate veins with small quantities of lead and copper. Sullivan Mining Co., and subsidiaries of Cyprus Mines Corp., Day Mines, and American Smelting & Refining Co. all have acquired property in this district.

Day Mines, Inc. has a DMA loan to assist in exploring the old Missoula Copper property and the Copper King property north of Mullan; and they have joined with Federal Mining & Smelting Co. in exploring the Independence Lead Mines east of the Morning mine.

In the northeastern corner of Washington—in Stevens County and in the Metaline district—and in an adjoining area of British Columbia, many companies are actively prospecting for and finding zinc-lead ores. These include Pend Oreille, American Zinc & Lead Co., Reeves McDonald, Canadian Exploration, and Consolidated Mining & Smelting.

The Ainsworth-Slocan area in British Columbia has been revived and the oldest lead mine in the Province, the Blue Bell, is again to become a 500-ton-per-day producer.

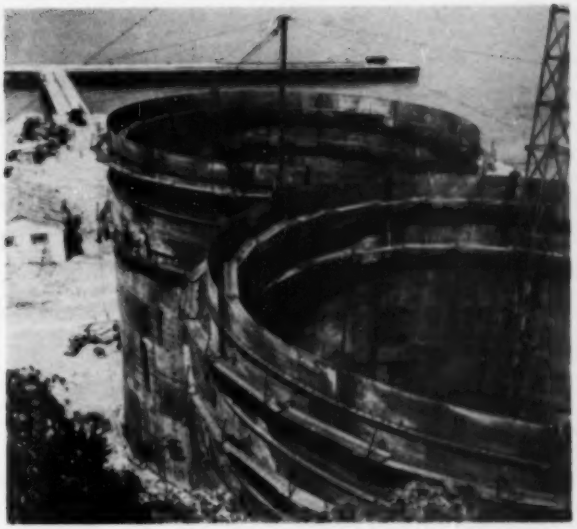
The high-grade, silver-lead-zinc-cadmium Silver Standard mine at Hazelton has sparked a new interest in central British Columbia, as has the Keno Consolidated in the Yukon.

At Pine Point on Great Slave Lake, Consolidated Mining & Smelting continued exploring lead deposits resembling those in the Tri-State area. A belt 30 miles long and 1 to 3 miles wide is now considered interesting, though it yet is too early to estimate grade and tonnage.

Quebec is to have another important zinc-producing area. The Barvue and Pershcourt properties west of Barrante share a large lens of zinc-silver ore that will be mined from open pits in 1952. These discoveries are credited to W. W. Weber, who mapped the region for the Quebec Department of Mines.

American companies are again taking an active interest in Mexican lead-zinc and other mineral

Reynolds, Alcan, and Kaiser are all developing bauxite deposits in Jamaica. Native labor uses hand augers for making exploratory holes.



First Jamaican ore is expected in the United States in September or October. Ocho Rios Bay, Jamaica, Reynolds' shipping point is equipped with storage tanks and loading pier.

prospects. Eagle-Picher Mining & Smelting Co., American Smelting & Refining Co., Peñoles Mining Co., Fresnillo Co., and others are busy examining and exploring prospects.

Fred Searls, Jr. writes that in Morocco, the extension of the Zellidja deposit across the line into Algeria has been proved, which adds a large tonnage of zinc ore, with minor lead content, in the territory of the Société Nord-Africaine du Plomb.

Copper

Copper Range Mining Co. has received a large Government loan to assist in developing its White Pine mine in the Nonesuch shale in northern Michigan. Calumet & Hecla Consolidated Copper Co. is carrying out exploration of some of its inactive properties with DMA assistance. Mingus Mountain Mining Corp. continued its study and exploration of the Jerome, Ariz., area throughout the year. Coronado Copper Co. has reopened its mine at Wilcox, Ariz., and is planning deep exploration.

Surface diamond drilling on the Merrill Island group held by Campbell Chibongaman Mines, Ltd. in central Quebec has demonstrated copper-gold ore reported to contain 1½ to 2 million tons. Exploration and rehabilitation of old mines such as the Ascot, Suffolk, Huntington, and Weedon in the eastern townships of Quebec continues. Noranda's large Gaspé copper deposit now indicates 57 million tons of low-grade ore and other nearby showings also are being prospected. Falconbridge has a government concession on a 2000-sq mi area north of Buchans, Newfoundland. The area includes the Gull Pond, Tilt Cove, and Rambler properties, which the company will buy from the owners. Drilling at Gull Pond has expanded reserves, and will continue this winter. American Metal Co. has recently staked a group of claims for copper in the Coppermine River area in Northwest Territories that it prospected some years ago.

Bauxite

Schmedeman reports that Reynolds Mining Co. increased their exploration for Arkansas bauxite over the 1950 rate, and discovered a major new orebody at a record depth of 600 ft. Reynolds, Alcan, and Kaiser companies are developing bauxite deposits in Jamaica. Tom Kesler writes that new bauxite deposits are being found in the Gulf Coastal Plain area as well as kaolin and fuller's earth deposits.

Sulphur

Many companies have been examining pyritic deposits during the past year as a hedge against a possible shortage of sulphur. Freeport Sulphur Co. took up a deposit at the eastern end of the Great Gossan Lead in Virginia, and General Chemical Co. bought the Stella mine in the western Adirondacks. Freeport has announced the discovery of an important new sulphur dome at Garden Island Bay, La. Other areas being developed are Starks dome and Bay Ste. Elaine dome in Louisiana, Spindletop dome, Tex. National Lead has had a DMA loan for sulphur dome exploration at Long Point dome, Fort Bend, Tex. Frobisher Exploration has taken over the Pilley's Island Pyrite property in Newfoundland.

Saline Deposits

Southwest Potash Corp., a subsidiary of the American Metal Co., has completed exploration at Carlsbad, N. Mex., and they and Duval Sulphur & Chemical Co. are sinking shafts. Freeport Sulphur Co. is continuing its prospecting campaign.

A new deeper deposit in the lacustrine section at Searles Lake, Inyo County, Calif., said to be higher in sodium carbonate and borate minerals and of wholly different mineralogy from the beds now being worked, is reported under development.

Asbestos

The Cassiar Asbestos Corp. has continued exploration of its deposit north of McDame Creek, B. C., where they have crysotile of good fiber length, quality, and grade in a serpentine body said to be 900 ft long and 400 ft wide.

Rare Earths and Gold

The Molybdenum Corp. of America carried out exploration of the Mountain Pass, Calif., bastnaesite deposit, and now is preparing to develop the deposit as an open-pit operation. At Grass Valley, Calif., the Idaho-Maryland is developing a new gold deposit in the southern part of the 6700-ft level.

Metal Mining in 1951

— — made progress in long-hole drilling, underground transportation, and ground support each being important in the battle of cost reduction.

by Tell Ertl

TODAY'S mining industry is witnessing a transition in labor utilization. The drill-jumbo operator, the mucking-machine operator, the blasting crew, the scaling and timbering crew are all specialists. The all-around miner is rapidly disappearing. As mechanization has resulted in a higher order of underground skills; specialization of labor has been a natural consequence, as has the need for more supervision and engineering.

Mines now are cleaner, neater, safer and have a greater productivity per man-shift than ever before. Nothing spectacular like the continuous miner has yet come to the underground metal mines, but a gradual improvement in methods, equipment, and technical knowledge is achieving the increased efficiency. With the exhaustion of the rich ores and large profits and who-cares-about-the-costs, mining has become a business; that of producing low-value ores at costs below selling price. Charles A. Chase, patriarch of Colorado mountain mining men, manager of the Shenandoah-Dives, was one of the first to preach and prove his preachings that mining is a business. He has been mining a lead-copper-zinc-gold-silver ore, much from elevations above 13,000 ft, for a quarter century without a shutdown. The ore is of such low value that most engineers and investors still would consider it foolhardy. Yet he has kept Silverton, Colo., alive, has paid wages without a lapse, has produced $25 million of new wealth and maintained a steady return to the investors. This type of responsibility is increasingly apparent in the mining business and is one feather that can be worn proudly.

Much emphasis is being placed on improving the productive mining operations—breaking, loading and transportation. Breaking in underground metal mining is done by drilling and blasting. To the writer's knowledge, no chain or rotary-type machine has been developed for mining strong, abrasive rock.

Drilling

Percussion drills are still the standard drilling machines underground. Diamond drills, that were the rage a decade ago for drilling long holes, are being superseded by the rock drill. The development of the hard abrasion-resistant carbide bit permits full-gage long holes to be drilled by percussion drills at a lower cost than diamonds. The change in the use of percussion drills is chiefly in the method of mounting. The column and arm are disappearing and the jackleg and rubber-tired or track-layer jumbo mountings are taking its place. At the Homestake mine lightweight jackhammers mounted on pneumatic legs using ⅞-in. hexagonal drill rods and 1⅜-in. tungsten-carbide detachable bits have been found more portable and maneuverable. They have less air consumption, lowered dynamite consumption, and more footage and tonnage per man-shift than with 3½-in. drifters on a column mounting.

Drills now are mounted on longer feed carriages, drilling up to 20 ft without changing steel. These mountings result in great savings because the driller can set up quickly, drill the entire depth of the hole without changing the drill rod or bit using carbide and one-use bits, and can move his machine quickly to the next hole. One man to the machine is becoming general practice. The result is longer rounds drilled at a lower cost than the previously used short rounds. A jumbo developed in the Tri-State can be extended to mine ore left in the roof up to 65 ft above the floor.

Drill-rod life was formerly considered to be about 250 min of actual use. The increase in the drilling time per rod per day has gone up considerably with the development of the jumbo and the long-feed carriage, resulting in which is apparently more rod breakage. Consequently, a great deal of research is being done in the attempt to develop an alloy-steel rod with longer service life to offset the greater cost. Some reports indicate that alloy steel or Swedish steel results in cheaper drilling than conventional drill rod. However, several tests have shown only slightly increased life for alloy drill rod. Undoubtedly, the blow of the rock drill, the length of the drill rod, and the resiliency of the rock being drilled are important factors in the life of drill rod, so it follows that alloy steel might work well in some mines and result in no savings in others.

The bit forged on the drill rod is seldom encountered and steel detachable bits are not as common as in the recent past. The one-use bit is gaining popularity because of the difficulty in rehardening reconditioned steel bits satisfactorily. It is thought that the carbide-insert bit is most applicable to drilling hard rock where the steel bit is unable to drill out a full change, for instance, in extremely abrasive

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Fig. 1—The Joy Drillmobile incorporates long-feed carriages mounted flexibly on a mobile vehicle. Models have been built with a 20-ft feed and to drill out headings 26 ft wide and 14 ft high.

jasper at the Sullivan mine and the Sudan mine. The insert bit is used extensively to drill long blastholes as at Holden mine. The weakness of the threaded bit connection is one disadvantage of the carbide-insert bit, and a typical solution to this is setting carbide inserts in forged bits. However, Homestake found that the inserts failed before the drill rod, resulting in higher drilling costs. Through testing, Homestake determined that the single-use detachable bit gave the best cost-per-foot, whereas the tungsten-carbide detachable bit gives faster drilling and longer rounds.

The trend is towards higher air pressures at the drill by improving pipe lines from compressors and using larger pipe. An increasing number of underground compressor installations close to the working face are seen. Development by Joy of a drill jumbo mounting an air compressor is giving increased air pressure at a lower cost. More and larger air hoses are used close to the drill, reducing labor costs because of the ease with which hose can be handled and moved.

Where drills still are carried by men, as in the block-caving undercuts at Climax, cast aluminum shells are used to save weight. For long holes, drill rods are used that have the same thread for the coupling as for the carbide-insert bit, permitting interchangeability of rods, thereby reducing delays caused by breakage.

Research drilling methods such as jet piercing, rotary, high-frequency and high-energy vibration methods are being investigated and may result in lower-cost drilling in the future.

Many of the new drilling practices are incorporated in the Joy Drillmobile shown in Fig. 1, on which drills with long-feed carriages are mounted flexibly on a mobile vehicle.

Blasting

No new explosives for underground hard-rock use are reported. The tonnage broken per pound powder, however, continues to increase. Because of the desire for longer rounds and their practicability with long sash jumbos, more burn-cut rounds are being drilled. Much of the saving in explosives per ton probably results from better technical supervision of blasting rather than better methods. The mines, that now are using smaller drill holes and less dynamite, were using large drill holes and too much dynamite. The technical man and good engineering pay off rapidly in such cases. Many miners have experimented with millisecond-delay blasting and some report reduction in costs. Millisecond delays are not yet as accurately timed as the mining industry would like them to be. In some of the iron mines burn-cut rounds are detonated by millisecond caps but the delays used are 75 milliseconds apart. Though closer spacing would be more desirable, the inaccuracy of the firing interval is enough to make the 75 millisecond delay imperative for breaking the cut successfully. Machine timing of circuits has been tried underground and is used successfully for extremely short delay shooting at Chuquicamata. In underground trials a spacing of 12 milliseconds, by machine timing, was found to give excellent results. At present millisecond-delay caps are not practical for face shooting because they cannot give accurate spacing and mechanical timing.

Climax has developed a number of novel labor-saving devices. All capped fuse is tipped with white paint so that the miner can tell whether he has timed it or not. A special semi-automatic powder punch has been developed by the powder man for preparing primers. The sticks of dynamite are placed on an inclined plane so that they roll down into a trough. A block of wood with brass pin is attached to the inclined plane so that it can be brought up to punch a hole in the end of the stick in the trough. With this device the powderman can prepare many sticks of powder per minute. Another labor-saving device used by the powderman at Climax is a windlass into which a primer is set and with rapid twisting of the crank the electric lead wires of the primer are wrapped easily around the stick of powder.

The shaped charge, which held promise for secondary blasting and even the drilling of holes, has been found too expensive for commercial mining operations in its present stage of development.

Much experimentation has been done at the Bureau of Mines oil-shale mine at Rifle in cooperation with the Applied Physics Division of the Bureau to attempt to learn the characteristics of the waves developed when explosives are detonated. Precise timing measurements were made at various places in the rock around the explosion to learn at what rates the waves travelled through the rock and how the shock waves were dissipated. This type of research,

Fig. 2—Eimco loader powered by a 250-hp. dc electric motor takes current from the trolley wire either with the trolley pole shown above operator's head or with a nipping cord.

Fig. 3—A self-propelled three-drum, scraper-loading slide is mounted on rubber tires for rapid maneuverability.

Fig. 4—Joy-type loader originally developed for loading coal and soft rock now is used increasingly for loading strong rock.

if continued, will permit choosing explosives with the most effective speed for breaking rock.

Loading

Loading is a mining operation that has been greatly mechanized. Chute loading with all its troubles still is commonly used. But more and more often stopes are being emptied directly on to the haulage level where the broken rock is picked up and loaded into the transportation device. Overshot rock loaders are the most common seen in underground metal mines. These often are compressed-air powered, but some Diesel units, and a-c or d-c electric-motor units, that take power from the trolley are used (see Fig. 2). Overshot loaders are used not only for loading from the horizontal but also for sinking inclined shafts with grades as steep as thirty degrees. The scraper or slusher loader still has many uses both in bedded deposits and inclined stopes; the self-propelled, rubber-tire mounted scraper slide shown in Fig. 3 was developed at the St. Joseph Lead Co. The Joy-type loader, Fig. 4, is being used increasingly in hard-rock mines. In the larger sizes these loaders are becoming competitive with shovels for loading in large underground openings. Crawler-mounted and rubber-tired front-end loaders are being used a great deal for cleanup, special jobs, and sometimes for production loading. At the Grandview mine a new type Diesel conveyance and loader for transporting ore from the stope face to the raise has been developed. The conveyance is track-mounted and Diesel powered. The trailer and loading bucket combined will load and carry five tons.

Transportation

Rubber-tired and conveyor-belt haulage are increasing in underground metal mines. To facilitate hoisting and conveyor-belt haulage, primary crushers also are being installed underground. Many of the standard-type trucks and shuttle cars have been used underground. Recent new types include the Joy Diesel-electric shuttle car, Fig. 5, the Le Tourneau Tournarocker, Fig. 6, and tractor-trailer units. Each of these types haul large tonnages in mines with minimum headroom of 8 to 10 ft and have excellent maneuverability. The Diesel and Diesel-electric drives are proving economical because of their flexibility over either the battery driven, trolley, or cable-reel drives. The Diesel-electric has an advantage over the straight Diesel mechanical drive because of the ease of maintaining close control.

Despite these advantages for the Diesel drive, they can be used only where adequate ventilation is available. The exhaust of the Diesel engine, though usually

Fig. 5—The diesel-electric drive of this Joy shuttle car gives more power than storage batteries and greater range than cable-reel type.

low in the poisonous gas carbon monoxide, nevertheless contains quantities of aldehydes that are irritating to the eyes, nose, and throat. Many types of scrubbers, more or less effective, are used. At Eagle-Picher, Diesel equipment has been used underground for several years and many methods of destroying the noxious gases have been developed. All exhaust gases now are passed through tanks filled with water, limestone, and copper wire. All such scrubbers require continuous attention to be efficient.

A great deal of underground conveying by belt is being done at the Inland Steel, Oliver, and Pickands Mather mines on the Mesabi Range. Miami Copper Co. uses a scraper-belt combination in four stopes. The belts, Fig. 7, are 30 in. wide and 200 ft long and are used in heavy areas, to permit placing haulage drifts to one side of the stope area. This prevents heavy maintenance on the haulage lines and interruption of train service for maintenance. At the Pend Oreille mine, the ore is transported from underground to the surface on a 1420-ft, 30-in. belt on a seventeen degree slope. The portal end is shown in Fig. 8. Before loading on the conveyor, the ore is crushed to minus three in. in an underground crusher, Fig. 9. The Cleveland-Cliffs Iron Co. overcomes the problem of transporting wet or plastic ores by putting a double twist in the belt so that the side of the belt that carries the ore never touches the idlers.

A recent improvement in hoisting technique is the Allis-Chalmers mine hoist remote control panel shown in Fig. 10. Because this console-type panel can be set up at any desirable location, the hoist engineer can operate the hoist in sight of the loading chutes or the discharge end rather than from the hoist house several hundred feet from the skip. This should result in fewer hoisting errors, increased speed, and efficiency of the hoisting operation. Quick-discharging bottom-dump skips again are becoming popular.

One phase of the transportation operation that is finding widespread application is electronic communication. Many of the mines visited recently, southeast Missouri, Climax, Barberton, Hanna Coal Co., and others were talking from the hoist-house, cage, locomotive or truck to any part of the mine. Most of these installations were satisfactory to the extent that it paid to use them because it speeded transportation and reduced the number of accidents. At one mine, electronic communication is credited with preventing a serious main-haulage wreck. Electronic communication may be a method of increasing safety and reducing mining costs. One mine man-

Fig. 7—A belt conveyor is used for ore transport in conjunction with slushing at the Miami Copper Co. The belt conveyors are being used to advantage to eliminate haulage drifts that would require excessive maintenance because of heavy ground under caved stopes.

Fig. 8—Portal end of the 17° belt conveyor used at the Pend Oreille mine for transportation of ore from underground. An underground crusher breaks ore to minus three in. before loading on belt.

Fig. 6—Le Tourneau Tournarocker is a new type truck for underground use. This type of unit hauls large tonnage in mines with 8 to 10 ft headroom.

Fig. 9—Pend Oreille ore is crushed in this underground crusher before being loaded on belt conveyor for transportation to the surface.

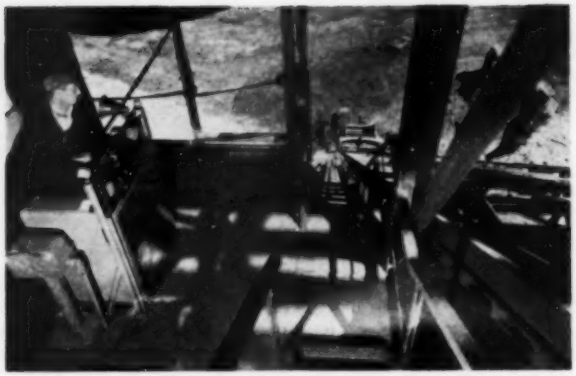

Fig. 10 — Allis-Chalmers remote-control, mine-hoist panel at use in a northern Minnesota iron mine permits the operator to observe the hoisting operation closely.

ager pointed out that special precautions are taken to shut off the electronic system when moving electric blasting caps because of the possible danger that the stray currents produced in communication may set off the blasting caps.

Other electronic devices, such as electric eyes for throwing switches and opening ventilation doors also are more widely used.

Nonproductive Operations

Improvements in nonproductive operations are keeping pace with those made in productive operations. The problem of support increasingly is considered from the structural rather than the superstitious standpoint. The Bureau of Mines, P. B. Bucky, C. W. Livingston, and others have made great advances in determining rock strengths and actions under mine stresses. Recently the Bureau of Mines has had some success in the direct measuring of stresses in pillars and roofs. This is done by placing a strain gage on the stressed surface, removing the stressed piece of rock by sawing it away with a diamond saw, and noting the relief of stress as recorded on the strain gage. As greater knowledge is gained of the mechanical properties of rock and greater use is made of the knowledge, mining recoveries and safety will increase and mining costs will be reduced.

Much more concrete and steel now is used underground for support of mine openings. Better methods for placing concrete now are available. Better types of steel sets and better means of applying them have been developed. Steel sets also are used in conjunction with concrete or reinforced concrete linings for support of heavy ground. A four-piece arch-steel set is used in the stopes at the Mather mine of the Cleveland-Cliffs Iron Co. The increased use of steel sets, steel construction, and mechanization underground has made it necessary to do considerable welding and cutting in the mines. Electric or acetylene welding machines have been placed on various types of portable carriers, bomb racks for one, for ready mobility.

For high open-stope mines portable scaling rigs that can reach the high roofs are used. One type is a telescoping tower carrying a platform from which the scaler can work. Another consists of an inclined boom supporting a platform that is kept level by a pantograph arrangement of the boom and ladderway. Both of these types are used for scaling where the roof is more than 50 ft from the floor. At least one rig has been built with scaling bars mounted on two hydraulic jacks in such a manner that the bar can be inserted behind a loose slab and the force of the hydraulic jacks applied to pry off the slab. Guns are used for scaling loose rocks that are inaccessible to rigs. The type commonly used is a mounted shotgun using a heavy lead slug instead of shot. The slug is fired against a loose slab with enough momentum to dislodge it.

One safety measure that is gaining new adherents daily is the use of Scotchlite, tiny glass beads on gummed tape. In many mines the miners wear strips of Scotchlite on their hard hats. It is used on signs numbering the stopes, pointing out safety stations or warnings of unsafe conditions. It comes in different colors and can be used on switch stands to show the motorman the position of the switch. A mine using Scotchlite liberally is a safer mine in which to work.

Outside construction costs are rising and because techniques of excavation and maintenance of underground openings are better, mine shops, compressor rooms, transformer stations, crushers and even mills are going underground. Mine maintenance costs are reduced when mine shops are close to the face. Compressed air pressures are higher and transmission losses are lower when the compressor is close to the face. Higher voltages are transmitted underground with a great savings in copper and transmission costs. With lower power and lighting costs more lighting is used underground resulting in increased safety and morale. Morale also is increased by the construction of clean, well lighted, heated lunchrooms. Better sanitary facilities and drinking water also make the mine more comparable to an industrial plant as a place to work.

The increased mechanization and production-line type of operation in mines requires a tremendous amount of planning and coordination of mechanical and human effort. No saving in costs results with the purchase of a 20-ton rubber-tired haulage vehicle if it is hand-loaded. The loading machine must have the capacity to load the haulage device within a few minutes so that it can be kept hauling. The ore pile which is being loaded must be large enough so that it is not loaded out in a few minutes, but rather should be enough to last a shift. To break a pile so large that it takes a large loader a shift to move it into large haulage vehicles, requires a wide, high and deep face. A high and wide face must be drilled by many drills or by fewer drills that are highly mobile. Furthermore to drill deep requires long-feed drills and long steel with abrasion-resistant bits.

Without careful engineering and planning, scheduling of operations and events, all high-capacity equipment may not result in reduced costs.

One of several taconite beneficiation plants springing up on the Mesabi Range.

Cheaper and Improved Methods of Beneficiating Lower Grade Ores Was Target in 1951

by Raymond E. Byler

THE challenge of unprecedented need for more metals to meet present-day re-armament and domestic requirements is being met with minerals beneficiation projects of great number and variety, and with new and improved methods, techniques, and equipment.

Iron Range Developments

Much attention has been given during the year to the tremendous program for beneficiation of taconites and intermediate iron ores which is progressing through large pilot-plant tests preparatory to full-scale production operations. The greatest activity has been directed toward concentration of magnetic taconites on the Mesabi Range. The Reserve Mining Co. has let $75 million in construction contracts for the 2½ million-ton-per-yr project (concentrates) at Beaver Bay, Minn., and is building a 300,000-ton-per-yr pilot plant to prove up the magnetic separation and pelletizing operations. Oliver Iron Mining Co. has a pilot plant under construction near Mountain Iron for concentrating magnetic taconites, and is operating experimentally a sintering and nodulizing plant on fine ore screenings and concentrates at Virginia to fully develop agglomeration technique. The Erie Mining Co. plant at Aurora continues its production of concentrates from magnetic taconites which was begun three years ago.

No plans have been announced to treat the Mesabi Range nonmagnetic taconites, but F. D. Devaney, Pickands Mather and Co., is studying a new process for magnetically roasting lean ores to make them amenable to low-intensity magnetic concentration.

W. R. Van Slyke, Cleveland-Cliffs Iron Co., calls attention to several noteworthy developments in the field of intermediate ores, perhaps the most significant of which has been the first commercial operation of a Dutch State Mines (DSM) cyclone plant at the Buckeye mine of the M. A. Hanna Co. The plant concentrates the +¼ in. fraction by means of conventional heavy-media treatment after suitable crushing, screening, and washing. The −¼ in. +65 mesh material is treated in two 12-in. cyclones, the −65 mesh fraction being sent to tailing storage. The plant is operating successfully on feed rates up to 120 tons per hr, and indicates that successful treatment of the fine fractions of Mesabi intermediate ores is imminent. Another commercial-size DSM plant was placed in operation late in the year by Cleveland-Cliffs at the Holman mine, and two additional ones are expected to be in operation next year. Various other methods are also in use at different plants for treatment of the fine fractions, including classification, abrasion milling followed by classification, jigging, and Humphrey spirals. Where it can be economically justified, it seems at present that heavy-media treatment of the −¼ in. fine fraction will also come into increasing use on the intermediate ores.

During 1951 a one-unit, heavy-media plant to treat hematitic crude ore was erected at the Ohio mine on the Marquette Range by Cleveland-Cliffs and plans for another plant at Humboldt to produce 2000 tons of concentrates annually is contemplated, as is also the construction of a plant for agglomera-

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tion of the concentrates. These plans indicate a spread of iron ore concentration into these regions. On the Menomonie Range the M. A. Hanna Co. built a pilot plant to treat the iron ore at Randville.

It has been announced that Cleveland-Cliffs and the Ford Motor Co. will construct a new plant utilizing the flotation process for the treatment of Michigan iron-bearing jaspers, and it is contemplated that pelletizing units will also be constructed.

Owing to the importance of converting fine concentrates into a form suitable for the blast furnaces a great deal of attention is being given by iron-ore-beneficiation metallurgists to the problem of agglomeration. Large scale experimental operations are being carried on utilizing sintering and nodulizing, heat hardening, the application of vacuum extrusion processes, and briquetting.

New Projects

Interest in hydrometallurgical processing widened during 1951 under the impetus of demand for cheaper and improved methods of beneficiating lower grade ores, and for recovery of some strategic metals which cannot be won economically by other methods.

Much attention is being given to the processing of domestic manganese ores. J. H. Jacobs writes that a 1000-ton mill is being constructed near Las Vegas, Nev., to beneficiate the Three Kids manganese ore deposit by flotation, and the U. S. Bureau of Mines began construction of a $600,000 pilot plant at Boulder City, Nev., to test a process combining flotation and hydrometallurgy on the low-grade Artillery Peak manganese deposits. The Western Electrochemical Co. constructed and placed in operation at Henderson, Nev., a 1-ton plant to produce battery-grade manganese dioxide by electrolysis of solutions derived from low-grade manganese ores, and is planning to expand capacity to 10 tons per day. One of the new processes announced for hydrometallurgical treatment of manganese ores is that of R. S. Dean who reports good recoveries obtained in tests on many ores. The process involves the use of ammonium carbamate as a lixiviant, which is prepared simply by passing CO_2 into concentrated ammonia, and it is said the volatile ammonia and CO_2 can be recovered economically from solutions and residues by heating, thus eliminating washing and evaporation. The product is a precipitate of manganese carbonate. R. V. Lundquist reports the results of experimental work carried out by U. S. Bureau of Mines in which manganese ores were leached with caustic soda solutions, removing soluble silica along with other caustic soluble minerals to yield a product containing upwards of 40 pct manganese from low-grade ores. The process would be used for upgrading ores.

Two new domestic operations which will alleviate the present shortage of cobalt were begun during the year. Howe Sound got its 1000-ton-per-day Calera project into operation in September. This operation will beneficiate the cobaltite-chalcopyrite ore of the Blackbird mine in Idaho. The ore is selectively floated after a long conditioning with lime at 80 to 90°F, the copper being floated first, then the iron, followed by flotation of the cobalt at an approximate pH of 4 with sodium sulphide conditioning. The copper concentrate is shipped to American Smelting & Refining Co.'s Garfield copper smelter, and the cobalt concentrates to Howe Sound's new cobalt refinery under construction at Garfield where the concentrates will be acid leached with electrolytic deposition of the cobalt, it is reported.

National Lead and DMPA are reported to have an agreement under which the recovery of cobalt will be resumed at Fredericktown, Mo. The cobalt-bearing mineral is siegenite which also contains nickel, and this metal will likewise be recovered. A production of the order of 7 million lb of cobalt and better than 9 million lb of nickel over five years of full-scale operation is expected. It is reported that the cobalt-nickel concentrate will be leached by a hydrometallurgical process in which the metal are individually recovered as a pure powder.

The Sherritt-Gordon project for production of nickel and copper at Lynn Lake was pushed during 1951, and a 50-ton-per-day pilot plant was operated at the property producing copper concentrate and nickel concentrate. The copper is to be smelted at Flin Flon by the Hudson Bay Mining and Smelting Co. The nickel sulphide concentrate is being treated in a pilot plant at Ottawa by the Forward ammonia leaching process which appears to give highly satisfactory results and which would eliminate preliminary roasting and other expensive preparatory operations. In full scale production the Lynn Lake operation is expected to produce 17 million lb of refined nickel per year, and about half that much copper. By-product ammonia sulphate from the process will be used for fertilizer manufacturing.

Research is being carried on by M. A. Hanna Co. and the U. S. Bureau of Mines to solve the problem of beneficiating the several million tons of 1 to 2 pct nickel ore in the Riddle area of Oregon. The mineral, which is garnierite, has resisted extensive previous investigations on concentration of the ore.

The Greater Butte project is another program aimed at exploitation of large low-grade ore potentials, which in this case is 130 million tons of 1 pct copper ore. About one fourth of the ore is strongly oxidized and troublesome metallurgically but F. F. Frick, Anaconda Copper Mining Co., reported that extensive metallurgical testing has fully developed a satisfactory leach-precipitation-flotation procedure for the oxidized ore. The remaining three fourths of the ore reserves will be concentrated by means of conventional lime-xanthate flotation.

The successful processing of low-grade ores and materials for recovery of uranium presents a strong implication of many advances in mineral beneficiation techniques, the details of which unfortunately are not available. Plans to recover uranium from the tremendous accumulation of old cyanidation tailings on the Witwatersrand are reported and also the proposed recovery of uranium as a by-product in the processing of phosphate rock at the new International Minerals & Chemical plant in Florida.

At the opposite end of the priority scale stand—or lie prostrate—the U. S. gold mining enterprises, and there is little new to report on beneficiation of gold ores. However, several outstanding projects came to fruition during the year. Golden Cycle got its new 1000-ton mill into operation on Cripple Creek tellurides and is now smoothing out its flotation-roasting-char cyanidation metallurgy. Two of the large new gold mills in the Orange Free State, the St. Helena and the Welkom, started up at mid-year using development rock to break in. Their cyanide metallurgy closely follows established practice on the Witwatersrand.

Grinding

Improvements in technique may well be exemplified by the coarse-crushing rod mill which now practically eliminates the last vestige of a line of demarcation between the crushing department and the grinding department. The 11½ ft diameter by 12 ft high-speed Hardinge rod mill installed by H. R. Banks in the Sullivan mill of The Consolidated Mining and Smelting Co. continues to pile up performance records. The mill reduces 1½ in. feed to −4 mesh product, and this large reduction ratio requires impact crushing in the rod mass which is obtained by a 670 fpm shell speed plus the use of unusually high 3¼-in. lifter wedge bars. The mill is handling 8000 tons per day and has so far crushed 5 million tons without relining. The Ni-hard shell liners and the conical end liners are still good, and the manganese steel wedge bars have been changed only once. This is a record which has never been equalled and it calls for a fundamental change in thinking in the matter of rod-mill capabilities. The mill is driven by a 1000-hp synchronous motor through an American Blower Co. fluid variable-speed drive which does not disturb the power circuit on starting, and which permits ready adjustment of mill speed.

Whether further gains in grinding efficiency are to be made by increasing shell diameters is questionable, and a practical limit in this respect may be the fact that a 13 ft shell diameter is about the largest that can be shipped by rail. J. F. Myers of the Tennessee Copper Co. points out that a comparison of the performance of high-speed, coarse-crushing rod mills with that of the conventional slow-speed rod mills such as at Hayden which give an efficient performance in finer size ranges, indicates strongly that rod milling may in the future be logically divided into coarse and fine rod-mill grinding, the coarse and fine mills requiring different dimensions and adjustments of rod action suitable to the range in which they would operate. Tennessee Copper now has on order a 7x7-ft rod mill which it will use for coarse crushing ahead of its present 6x12-ft fine-crushing rod mill.

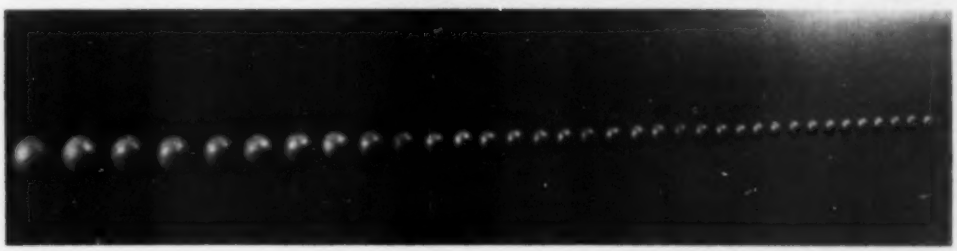
The pattern of open-circuit rod mills to closed-circuit ball mills is becoming more prevalent where relatively large capacities are required, and particularly when handling sticky clayey and moist ores which cause trouble in fine-reduction crushers. The over-all power advantage over the reduction crusher is questionable but there is reported to be considerable gain in ease of operation, simplicity, repair, and labor costs. Not all operators are convinced, however, that multi-stage grinding is necessary or desirable particularly in those cases where the ultimate grind required is not so fine. The new 5000-ton-per-day Barvue mill at Barraute, Que., for example, will use single-stage, ball-mill grinding to produce 48 mesh feed for its zinc-sulphide-flotation concentrator. Conversely, Union Minière du Haut Katanga is installing four open-circuit rod mills to be followed by eight closed-circuit 9-ft Tricone mills. This ore is somewhat sticky and a coarser product from the reduction crushers is considered advisable. At the new Creighton concentrator of International Nickel which went into production in September, 10,000 tons per day are ground in a two-stage operation with 10 ft 8 in. x 13 ft long Marcy mills, the primary units being rod mills and the secondary units ball mills, with 70-ton loads in each.

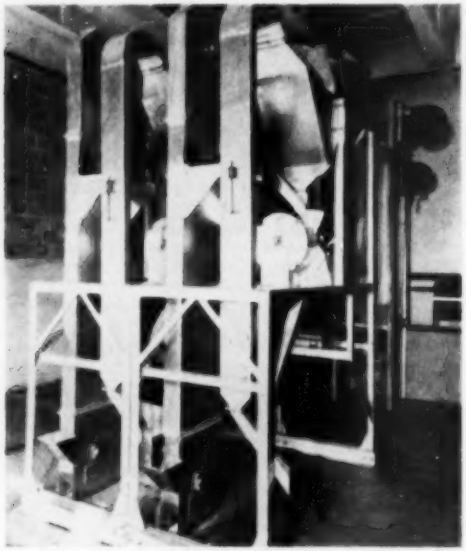
Pursuing a study of grinding ball action, Tennessee Copper now reports the finding of two completely round ball strings taken from different mills, in contrast with the polyhedron shape of the smaller ball sizes previously reported. With this evidence that rolling balls all the way down in size do exist, they forecast that efficiency in ball-mill grinding can be expected to increase if the rolling action of slow-speed ball mills could be enhanced so that all balls roll. It was also observed that, whereas Sheffield Moly-Cop balls stayed round after surface pitting, the high-carbon steel balls became slick and slide and lose their shape soon.

It is reported that the performance of spiral liners has shown during the past year that these liners cause ball segregation which in turn allows a greater through-put for a grinding mill, and a more effective reduction of coarse particles is obtained and over-grinding of fine particles is reduced. Rail liners are being used in an increasing number of mills and users claim no sacrifice in mill grinding capacity, but a considerable reduction in lining costs. The undercoating now generally applied to automobiles, is being used as a protective coating for ball-mill shells. It is easily applied and is reported to be effective. The use of alloy liners and lifters is growing, and another case in addition to that already cited was reported during the year in which Ni-hard liners showed only 25 pct total wear after 19-months operation in a 9x12-ft rod mill compared with former liners which had to be replaced after 9 months on the same type of duty.

Interest in pebble mills has been revived by the successful changeover from steel balls to screened ore for grinding media in the tube mills at Lake Shore. B. S. Crocker has reported that the changeover to screened ore for fine grinding has reduced costs 26 cents per ton milled, principally through eliminating the cost of steel balls. The screened-ore media is equally efficient and so much more flexible

Evidence that rolling balls do exist all the way down in size is represented by this photograph of a round ball string of Moly-Cop balls from one of Tennessee Copper Co.'s mills.





The Mardun disintegrator is a new attrition grinder for either wet or dry selective grinding. The USBM 1000-lb-per-hr unit at the Salt Lake station is shown here.

than steel-ball grinding, that Lake Shore does not consider it war-time expediency. Conversion of the 5x16-ft tube mills for pebble grinding was accomplished principally by fitting with a larger shell and reducing the mill speed so that the motors could be operated at full load. A low discharge grate with lifters was found more suitable for pebbles and gave a 40 pct higher capacity than the high discharge pebble mill. It was also found that the capacity of the screened-ore grinding media is directly proportional to that of the steel balls in the ratio of the respective specific gravity.

Use of screened ore for grinding has also been instituted at the Wright Hargraves mine with a substantial saving in cost reported, and the similar use of screened-ore pebbles as a substitute for steel grinding balls is currently being studied at the Neptune mine of AS&R in Nicaragua, where it is thought that savings as high as 30 to 40 cents per ton may be effected in view of the fact that freight has to be flown in to the mine at a cost of $60 per ton.

There appears to be a definite trend in the cement industry toward the use of short-barrel grinding mills, close circuited with air classifiers and operated with high circulating loads. These mills are being used instead of the old long-tube mills operated in open circuit. It was felt for many years that open-circuit grinding with its overgrinding, was necessary to obtain the required specific surface for the final product. Strength tests have shown however, that although cement prepared by closed-circuit grinding is not as strong as cement prepared by open-circuit grinding after three days, it becomes stronger after 28 days. Even old tube mills or compeb mills are being redesigned for closed circuiting. A center peripheral discharge compeb mill has also been designed.

The Mardun Disintegrater is the subject of a paper being prepared by Schack and Zimmerly of the USBM in which results obtained with this new type of attrition grinder are reported. The grinder is applicable to either wet or dry selective grinding and reduces the soft or friable constituents of a feed to dust or slime that can subsequently be separated from the sandy residue of harder minerals by air or water classification. The field of usefulness is definitely related to the physical nature of the ore and is limited to soft minerals such as sulphur, graphite, bentonite, and mica, and certain cemented sandstone ores. Multiple stages of disintegration are usually necessary.

The dissection of the comminution process is continuing to throw new light on an old subject. In an effort to resolve the shortcomings and anomalies of both the Rittinger and Kick theories, Fred Bond, Allis-Chalmers Mfg. Co., has derived a third theory which postulates that the total work used in breaking is inversely proportional to the square root of the diameter of the product particles. The theory gives values which are consistent over all size ranges for a number of actual plant crushing and grinding operations, as well as for many laboratory grinds. It differs from the strain-energy theory of Bond and Wang advanced in 1950 and is reported to permit closer prediction and more accurate comparison of crushing and grinding installations than has heretofore been possible.

Gaudin, Spedden, and Kaufman of MIT published the results of an interesting research on "Progeny in Comminution" in which the use of radioactive tracers permits going beyond the usual statistical limitation of size-distribution studies, and following the progeny from reduction of marked size fractions in an environment of all sizes. The method may be effective in dealing with problems involving circulating loads which cannot be dealt with adequately by techniques previously available.

Operations of the impact-type breakers on lead-zinc and gold ores during the year have indicated that on hard ores excessive wear makes maintenance a serious problem and apparently the high one-stage reduction ratio of this type of crusher can only be utilized in processing softer ores and materials.

Screening

A new approach to screening was presented in 1951 by Frederick Mogensen of Djursholm, Sweden, who uses a series of screens all of the same aperture to produce undersize of a much smaller dimension, the principle involving the probability law. The Mogensen sizer consists of a set of 5, 10, or more sloping screens placed one above the other with suitable spaces between, in a single vibrating frame. With a 10-mesh aperture in all of the screen decks, for example, and feed consisting entirely of particles finer than 35 mesh, the sizer delivers products which vary from the finest material nearest the feed end to the coarsest particles nearest the discharge end with a gradual variation of the sizes in between so that a split can be made at any desired size by simply placing a partition in the undersize hopper at the proper point. Apparently particles of high specific gravity find their way through the nest of screens more quickly than those of lower density, so that the device might be also used for preparing feed for gravity or flotation concentration. A full scale Mogensen sizer is in use on iron ore in Sweden working in closed circuit with a grinding mill and it is reported that, unlike a rake or spiral classifier in the same work, it is producing an impoverished return to the ball mill rather than an enriched one.

A more extensive use of electrically-heated

screens has developed during the year which are said to do a good job of staying open when handling wet or sticky material. However, it takes longer to change screen cloths because of the accessory equipment and if a screen cloth of another diameter or composition of wire is to be used, the resistance is changed and the electrical circuit has to be readjusted accordingly.

Classification

The Dorr Hydroscillator continues to increase grinding efficiency by elimination of critical size material and greatly reducing the undersized in the rake product returned to the mill. Tennessee Copper reports that the Hydroscillator helps control the rate of oxidation in the flotation feed. Frank A. Ayer, Copper Range Co., advises that the Hydroscillator installed recently in place of the rake classifier in the grinding circuit of the White Pine pilot mill appears to give the mineral particles in the pulp a better washing action which eliminates the adverse effect of slime and clay in subsequent flotation with the result that the grade of concentrates increased from 25 to over 35 pct without impairment of recovery since the Hydroscillator was installed.

Materials Handling

Belt conveyors are getting super colossal and the big ones are doing things far beyond the economic scope of truck haulage or aerial tram. A new 36-in. belt-conveying system being installed at the Wabana mine, Newfoundland, will transport 1000 tons per hr for 12,500 ft with a lift of 1700 ft, at a belt speed of 575 fpm. The South Agnew stripping job on the iron range involves a conveyor system handling approximately 2200 tons per hr for a distance of 8000 ft. The longest single belt conveyor in existence today appears to be the National Mines conveyor belt. This is a 30-in. belt which transports 216 tons per hr for a distance of approximately 10,900 ft, with a grade average of about 2 pct in favor of the load. The belt conveyor under consideration at Seven Islands terminal for Labrador ore will have a capacity of 8000 tons per hr. Large capacity is an undisputed advantage of the present-day conveyor and it is characteristic that installation costs per ton-hr capacity decrease rapidly as the tonnage to be carried increases.

A new belt duck of nylon and specially-treated cotton fibers is reported to possess great strength permitting longer centers, higher lifts, and greater load capacities to be used in conveyor installations.

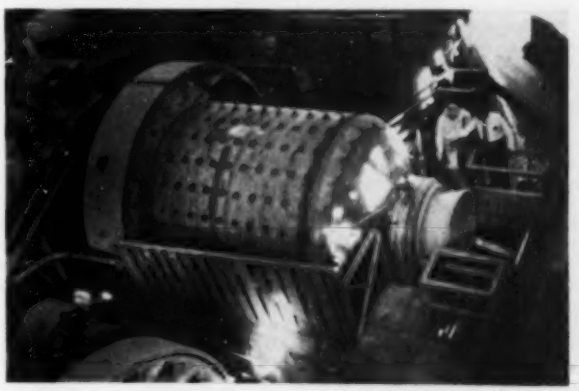
Mechanized mining and loading methods have greatly increased the opportunities for tramp iron to get into the ore stream of large long-haul belt-conveyor systems and thought is being given to increased protection for crushing, processing, and conveying equipment. R. L. Manegold, Dings Magnetic Separator Co., has a new design of rectangular-shaped suspended magnet which provides a solution to the tramp-iron problem even in cases where there is 30-in. clearance between the conveyor and the suspended magnet. At Tennessee Copper, Myers suspends a magnet over the deck of the ore screens where it is more effective in collecting tramp iron than when suspended over the deep bed of ore on the conveyor belt. Manganese steel wire cloth is used to avoid damping of screen action by the magnet.

A new means of checking measured ore tonnages, is given by the Merrick High-Low weightometers which are now available for use on the same belt, one weighing half the load range and the other the remaining half. An antomatic shifter is provided for switching from the low to the high range and vice versa. This is an alternate to the device of installing dual weightometers, each operating on the same belt one as a check against the other.

A new development of much interest in pumping, which has been undergoing field testing for several years at the Balmat concentrator of the St. Joseph Lead Co., is the use of abrasion-resistant, silicon-carbide follower plates, casings, and runners for centrifugal pumps. While these parts cost two or three times as much as ordinary steel parts, wearing life offsets the cost many times. For example, a follower plate in one pump had a life of 836 days as against a 60-day life for steel; a pump casing of silicon carbide has been in continuous use since 1948 whereas the life of a steel casing averaged 61 days. An impeller had a service life of 400 days in comparison with 7½ days for steel, and had to be replaced because of accidental breakage—the actual wear being negligible. W. M. Wheildon, Norton Co., advises that the Balmat mill has been completely equipped during 1951 with the Crystolon silicon-carbide pump parts.

Gravity Concentration

Heavy-media separation continues to increase in usefulness as a means of upgrading ores or producing finished products. S. A. Falconer, American Cy-



This 11½x12-ft Hardinge rod mill at Chapman Camp of COMINCO, is piling up performance records—8000 tons per day, 5 million tons without relining.

anamid Co., advises that there are now 135 heavy-media separation plants in operation or under construction, treating over 55 million tons per year of various types of ores. It is estimated that in 1951 over 5 million long tons of shipping-grade concentrates were produced by concentration of hematite ores by this process. It is presently being used in the beneficiation of andalucite, brucite, chromite, diamond-bearing ground, fluorspar, garnet, gypsum, hematite, lead, zinc, manganese, magnesite, pyrite, spodumene, tin and nickel silicates, as well as coal and concentrate aggregate, the latter in Canada.

The use of magnetically-recoverable media is gaining favor for some applications, and during the year Grove, Brackin, and Polhemus published the results of operations at Mascot where an appreciable savings in cost as well as an improvement in metallurgy was obtained by changing from galena media to ferrosilicon. The authors report that the chief advantages of the ferrosilicon circuit lies in its simplicity and the elimination of the possibility of contaminating the zinc concentrates with galena.

H. F. Lynn, Southwestern Engineering Co., writes that heavy-media equipment suppliers are directing their attention to improvements which will expand the size range that can be handled. At present it varies between 7x3/16 in. in a coal operation at Rawl, W. Va., where equal separating efficiency in all sizes ranges is obtained, to ores of $-\frac{1}{8}$ in. x 60 mesh at the Helen mine, Ontario, Canada. Control of the middling product is now becoming practical as evidenced by the operation of the washery at Crystal Black Coal and Coke Co. in which the middling product is continuously removed with less than 1 pct misplaced material.

The improved design and efficiency of the new Dings heavy-media magnetic separator gives better operation in recovering magnetite and ferrosilicon. The Jeffery-Steffensen drum-type magnetic separator has recently been improved by changes in feed and discharge arrangements and is undergoing investigation for use in recovering medium in Dutch State Mines cyclone separator plants on the iron range. An exceptionally high recovery of ferrosilicon medium is made at Mascot by use of two separators in series which protects against overloads. A 24-in. Stearns Type MWI magnetic separator and a 36-in. Dings-Crockett are used.

The old and ancient method of upgrading ores by hand sorting is reducing milling costs 15 pct at the Silver Belt mines, Ophir, Colo., where the ore goes through a washing plant to remove soft clay gouge before passing to the sorting belt. Approximately 20 pct of the ore is discarded in the sorting operation according to Smith and Ferguson. The use of a photoelectric concentrator to sort out high quality optical fluoride crystals has been successfully carried out by Turrall and Porter at MIT. A long look ahead was taken by Gaudin and Senftle of MIT who appraised the possibilities of using slow neutrons to sort minerals and ores, and conclude that, on the expectation that great strides will be made in nuclear engineering, practical use of nuclear sorting may in the future be applied to many ores.

Interest expanded during the year in the use of wet-type cyclones for classification, thickening, and desliming operations, and many applications of this tool were extensively tested on various materials and metallurgical products. As a classifier it is reported to make separations in which the top size in the overflow is as fine as 10 microns. At the Homeland mine of the Virginia-Carolina Chemical Co., a 24-in. test unit deslimed −14 mesh phosphate rock ahead of flotation, eliminating better than 90 pct of the slime and recovering 97 pct of the valuables in an underflow product which averaged between 70 and 76 pct solids. O. C. Chapman and H. L. Pascoe will disclose shortly subsequent operating data of a 24-in. Dorrclone desliming washer debris at 150 mesh, and dewatering flotation feed.

A new form of cyclone was introduced during the year by Equipment Engineers. This is the Centriclone classifier which uses a power-driven rotating internal impeller to obtain high cyclonic forces and which permits independent variation of residence time and velocity. It is also used in thickening and dewatering, and it is said to give unusually sharp cuts in sizing jobs. Krebs reports that on a −20 mesh slurry at 25 pct solids containing 40 to 50 pct −325 mesh material, an overflow of 100 pct −325 mesh with an underflow of 4.7 pct −325 mesh was obtained. On ball-mill discharges, it returned tramp oversize up to 6 mesh in closed circuit, producing an overflow of 98.2 pct −200 mesh at 61.5 pct solids and an underflow of 69.8 pct plus 200 mesh at 81 pct solids.

The new Centriclone classifier uses a power-driven rotating internal impeller to obtain high cyclonic forces and independent variation of residence time and velocity.

Progress was made during the year in the development of filters to handle taconite concentrates, which cannot be handled satisfactorily by standard metallurgical filters. P. J. McGuire, Oliver United Filters, advises that a special filter is under development to improve speed and ease of cover changes, with improved agitator construction to provide better agitation and improved tank design for cake discharge. Reduced over-all maintenance costs are essential for operation on taconite concentrates. In the field of dewatering foundry sands and glass sand, the horizontal type of continuous rotary vacuum filters is proving satisfactory, and its use for dewatering

At the Siglo XX plant of Patino Mines, Catavia, Bolivia, Heavy-Media Separation is used to concentrate tin ores. Two 10-ft separatory cones handle the 1½x5/16-in. and 5/16x1-mm fractions, respectively, at the combined rate of 125 tons per hr.

granular pyrite concentrate is also a new development. Filter media constructed of various plastic fibers are giving improved operation results at reduced costs, and there is an increasing range of available cloths in various weaves to choose from.

Studies of the phenomena taking place in flotation continue to add to knowledge of the process. Philippoff, S. R. B. Cooke, and Cadwell, University of Minnesota, report that they find a definite relationship between contact angle and percent surface coverage of the mineral particle by a collector, which is thought to result from a difference in the type of film formed on the surface at small and at high concentrations of the collector molecules. Studies of the mechanism of attachment of a conditioned mineral particle to a rising bubble indicate that it is a high-speed phenomenon dependent on the velocity of film recedence under surface tension, and that any long-time effects are improbable.

Further light on the nature of a collector-coated mineral surface has been shed by Hassialis and C. G. Myers, Columbia University, who present evidence that collector ions are mobile in the solid-liquid interface, and postulate that this mobility plays a part in the transitory state through which the system passes in attaining equilibrium and may explain certain induction-time phenomena in developing contact between bubble and collector-coated surface.

Gaudin, Spedden and Corriveau, MIT, published results of further studies with radioactive tracer elements in flotation research. The mechanism of activation processes involving ion exchange, such as the activation of sphalerite by copper ion was investigated in preliminary studies utilizing radioactive silver as the exchange ion in place of copper.

Radiotracer measurements were used by C. M. Judson and co-workers, American Cyanamid, to follow sorption and distribution of a dithiophosphate collector in flotation of galena and sphalerite.

G. A. Last and M. A. Cook, University of Utah, report the results of a study of collector-depressant equilibria at mineral surfaces, and postulate a theory of equilibrium based on single-site adsorption of collector and depressant-free acids.

Based on the hypothesis that a mineral has a potential flotability determined by its previous treatment, Arbiter, Phelps Dodge Corp., develops a means of evaluating the comparative efficiency of flotation operations and flotation machines by using rate constants, and shows that a simple rate law appears to govern.

Two new flotation reagents were recently introduced. A water-soluble frother, Dowfroth 250, permits closer control of frothing, and a new auxiliary promoter and froth modifier, Cyanamid's S-641, has been effective in scheelite flotation.

The expanding use of flotation in the treatment of nonmetallics continued throughout 1951. At least six flotation plants are now in use in this country for up-grading glass sands by removal of iron, feldspar, and other objectionable impurities. The recently developed 800 Series reagents are used at several of these plants for removal of iron-titanium bearing impurities.

Considerable work is being done at the Diamond Research Laboratory in Johannesburg, on the use of flotation for commercial recovery of diamonds. It has been reported that diamonds with water repellent surfaces less than 16 mesh in size can be quite satisfactorily recovered by flotation in a mildly alkaline circuit using Aeroflot 25 with a frother. Diamonds having hydrophilic surfaces are partially recovered by precoating with a fatty-acid soap or cationic amines which give a water repellent film to the diamonds. Excellent recovery of fine crushed boart can be made from wastes of industrial users by first conditioning with the fatty acid, washing, and floating in a pneumatic-type cell.

The use of flotation for recovery of fine coal has continued to grow during the year. The Lehigh Navigation Coal Co. completed the second flotation plant, a 50-ton-per-hr installation to recover anthracite fines ranging from about 35 mesh to 200 mesh in size. The construction of another large 150-ton-per-hr flotation plant for anthracite fines is also reported.

The improvements in roasting techniques obtainable with the Fluosolids roaster were demonstrated in further applications during 1951. It is reported that eight plants are now in operation with eight more under construction. Although most of the troubles connected with the mechanical operation of these roasters have been effectively dealt with, there is apparently some difficulty at times with dust losses. To correct this at Golden Cycle a Cottrell precipitator is being installed following the multiclones.

Lastly, and properly at the end, it should be noted that mineral beneficiators are looking to extracting the last squeal from the tailings. An outstanding example is the Consolidated Mining and Smelting Co.'s project for recovery of sulphur from the Sullivan concentrator tailing by roasting. The sulphur will be used to supply sulphuric acid for the $9 million ammonium phosphate fertilizer plant now in construction.

Open Pit Mining in 1951

better design in shovels
mechanical advances in trucks
operator comfort in bulldozers

This Bucyrus Erie 150B shovel, introduced in 1951, features double twinned hoist lines, tubular dipper stick, and rope crowd.

by C. E. McManus

MANY mechanical advances have been made on mining equipment during the year 1951. There have been a number of trends established and many modifications made on open-pit equipment to increase the efficiency and availability of all the machines necessary in the moving of overburden and iron ore. Some years ago, the trend toward larger shovels for the loading of off-highway trucks began, but in the last year, it has become general practice to use the 5 to 7¼-yd quarry-type shovels in the loading of haulage units.

For years these larger shovels were used in the locomotive haulage pits. As the truck capacities increased from 15 to 20 to 30 tons, the need for larger loading units became apparent. Today in most mines, large shovels are in evidence and a few 8-yd shovels will be delivered this year for loading off-highway trucks.

Torque Converter-Shovel

The Diesel-driven shovel with its friction bands has been modernized with the torque converter. There have been about ten shovels remodeled to take a torque converter in the drive system. The large high-torque, low-speed Diesel engine was removed and replaced by a high-horsepower, high-speed, automotive-type engine. This engine was connected directly to the torque converter. The torque converter was connected to the shovel through the standard original sprocket and chain. Dual governors controlled engine performance. One governor controlled the high idle of the engine; the other governor, which is connected through a flexible shaft to the output shaft of the converter, controlled the loading of the engine. With this dual governor hook-up, the engine anticipates load conditions and is operating at high idle and full throttle before the shovel load is transmitted back through the converter to the flywheel. It has been found that with this automotive-type engine and converter, the shovel capacity has been increased about 20 pct. Also, the wear on the friction bands, breakage of hoist cables, and other mechanical breakages has been reduced materially.

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Alloy-Steel in Shovels

The shovel equipment manufacturers have been experimenting with low-temperature-strength, high-alloy steels to combat the excessive breakage that occurs in extremely cold weather. High-nickel alloy steel has been used in critical areas that are affected by low temperatures, the most notable being dipper sticks. Most shovels ordered today are equipped with some of this special, alloy steel. More and more manganese alloy is being used for replacement parts such as shovel pads, idlers, drive sprockets, etc. Although the initial cost of these parts is considerably higher than the standard replacement items, the life of these manganese parts is considerably longer and well worth the added expenditure.

Dipper-teeth repair is still a problem. Most companies use the small replaceable inserted tooth. It has become common practice among some of the companies to "job out" their dipper-tooth repairs to outside welding companies. This necessitates an additional inventory of teeth, but it does guarantee an adequate supply of replacement teeth at all times. These contractors have set up their shops on a production basis and can do an acceptable job at a high rate of speed. Thermite welding has been used in retipping teeth. To date, the process cannot be called successful but with improvements the time required to repoint the dipper teeth will be decreased considerably. The submerged arc process has been tried in the replacement of these dipper points, but like thermite welding has not proven successful. Here again, if a method can be developed to use submerged arc, the job of teeth repair will be made much easier.

New model shovels in 6½ and 8 cu yd sizes fea-

ture rope crowd, tubular sticks and double-twinned hoist lines. The latter permits use of lighter rope and smaller diameter drums.

Lubrication of the moving parts on a shovel has always been a serious item, particularly in cold weather. Considerable interest and activity has been shown in centralized lubrication. With these centralized systems, one pump can lubricate a multiple group of fittings. The grease pump can be connected in two different ways; first, the pump can be actuated by the shovel oiler who periodically lubricates the shovel by hand operating the primary pump; second, the system which may prove the most desirable is actuated by the movement of the working parts of the shovel. In the second method, there is a constant supply of grease or oil being fed to the moving parts. A centralized greasing system does require a considerable expense for installation, but if the shovel's critical parts can be supplied sufficient lubrication at all times, much wear and costly down time will be eliminated.

Trucks

The most notable development in off-highway truck haulage in the last year has been the introduction of a 50-ton end-dump truck. This truck is equipped with two 300 hp supercharged, Diesel engines. Each engine drives a torque converter and a semi-automatic transmission and one of the twin, rear-drive axles. The truck is equipped with ten 18:00 x 33:00 tires and empty weight of this vehicle is 93,500 lb. The truck box, less sideboards, has a capacity of 32 cu yd struck measure. This truck has performed satisfactorily, but due to its size, certain modifications must be made in pit layouts.

The trend in the last year has been toward larger trucks, notably of the 30-ton size. There have been 185 30-ton trucks delivered in 1951, which is 60 pct of the total trucks delivered to the range in 1951. All of these 30-ton trucks are equipped with tandem axles, since the single rear-axled 30-ton trucks are no longer meeting with favor on the iron range. The engines in these trucks vary from one 300-hp single engine to two 200-hp or one 400-hp engine.

The torque converter has definitely come into its own, 72 pct of the trucks delivered this year have been equipped with converters. Most converters are single-stage, but the three-stage unit is being given more consideration. In conjunction with the converters, semi-automatic transmissions are being used in a number of installations.

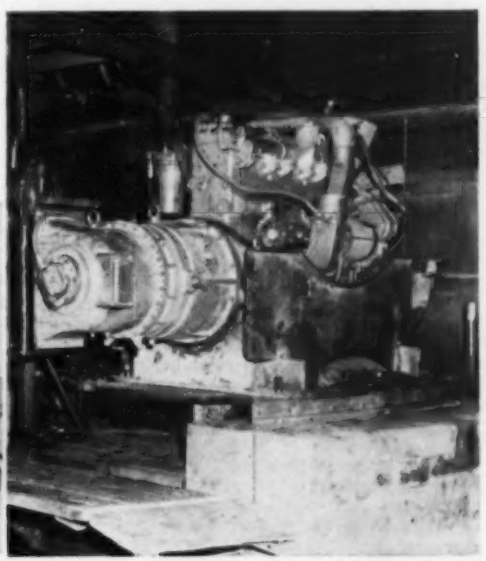
The problem of maintaining engine temperatures has been worked on for a number of years, but to date, there has not been a satisfactory solution. Automatic shutters are meeting with almost universal acceptance, however, the automatic shutter will not do a complete job in maintaining proper engine temperatures. Variable pitch and electrically-controlled, variable-speed fans have been the trend and found wanting. A few pneumatically-controlled, variable-speed fans have been installed and on trial for the last year, giving a good account of themselves. A desirable feature of this fan is that if a failure occurs, the fan locks up positive, so that the engine is cooled at all times, eliminating the danger of overheating.

To combat overheating or running the engine without proper oil pressure, electrically-operated warning systems have been installed on a few trucks that were delivered this year, but many difficulties were encountered. There are also a few units that are operating with a pneumatic warning system and this appears to have good possibilities. As the power plants become more complicated and more expensive, it is imperative that some system of warning be given the driver before unnecessary damage is done.

Larger horsepower engines have high electrical demands for starting. In view of this situation, air starters have been tried and two fleets have been delivered with air starters as standard equipment. These air starters make it possible to operate the electrical system on 6 v. This, of course, simplifies electrical wiring considerably. In conjunction with these air starters, a-c alternators and rectifiers have been used. The a-c alternator will generate proper voltage when the engine is idling, and this is par-

A 22-ton Euclid (below) with exhaust heated body raised to show front under-body exhaust connection.

Torque converters have increased some shovel capacities up to 20 pct. The installation shown at right was made in a 548 by Hanna-Crosby.



The latest arrival to the range has been the 50-ton truck, shown for comparison here with the 15, 20, and 30-ton models in that order from left.

ticularly advantageous in the winter time when the demand on the electrical system is at its highest. The idling time for the engine, particularly in the winter, can be so long that a d-c voltage generator cannot keep the batteries adequately charged.

Practically all the trucks being delivered are equipped with exhaust-heated boxes for winter stripping. There are some stripping materials and ore that require heated bottoms even in the summer time to dump and clean successfully.

More attention is being paid to the lubricating oil that is added to the truck engines and its condition during engine operation. One company has set up its own laboratory facilities, and a contractor has set up a shop to take care of a number of mining properties in the analyses of lubricating oil. A sample was taken from each engine each day and analyzed for dirt, bearing material, and dilution. Through this analysis, the condition of the engine can be checked each day. Previously, oil filters were changed after a certain number of operating hours. With this new type oil analysis, oil changes and filter changes are dictated by the results of these daily samples. Oil, oil filter, and engine life has been extended considerably by this oil-analysis service. A number of mining companies are now filtering all fuel oil before it is pumped into the trucks. This filter does two things: first, it removes foreign material such as scale, sand, or dirt; second, it removes water. Any abrasive impurities shorten fuel-pump and injector life. Water, particularly in the winter time, can cause considerable trouble, for as the cold fuel approaches the cloud point, wax precipitates around the water crystals. This wax will eventually plug the fuel filters.

Radiator water is also receiving more consideration, with some companies installing filters and water softening units. This soft, clean water definitely increases water-pump-seal life and also aids in the prevention of scale formation inside the engine block and cylinder heads, thereby, maintaining the high heat-rejection characteristics of the cooling system.

Five-degree tapered rims are now coming into general use. These rims have proved advantageous whenever tires are unintentionally run with low pressures because the rims hold the tires tight enough to prevent rotation. There is ample evidence to prove that all movement between the toe of the bead and the rim has been eliminated. All carcass flexing now occurs in the sidewalls and the crown and no longer in the bead. This should increase tire life. There is one disadvantage in the 5° tapered rim, without proper equipment, the removal of the tire from the rim is extremely difficult.

Bulldozers

Bulldozers have been in the process of change for the last two or three years, the trend is toward higher horsepower and heavier machines. With larger shovels and trucks, and increased yardage handled per shift, the problem of disposal on the dumps and cleanup around the shovel has increased. To meet these demands, larger and more efficient pushing units are being developed. Torque converters also are entering this picture. Rubber-tired dozer of the four-wheel-drive type are commonly used. These machines do a creditable job in certain operating areas, with limitations, but their high flexibility and speed makes them a desirable piece of equipment for open-pit operation. A new heavy, high-horsepower, rubber-tired, rear-axle-drive bulldozer was introduced last summer. The tractive effort and the blade width approves that of the heavy-crawler tractors. Rock blades with 3-ft tines have been used on rock dumps. When the material is dozed over the edge, the finer particles sift through the tines, leaving a layer of fine material on the top of the dump that can be graded easily with the motor graders. This, of course, increases truck tire life. Enclosed, heated operator's cabs have been mounted on the crawler-type tractors. Some difficulty has been encountered in keeping these cabs mounted rigidly on the tractors, due to the characteristic vibration of these crawler machines.

During last year, crawler track pads and rails have been very difficult to procure, resulting in a heavy salvage program by all operators. New techniques of rail salvage have proved that this work is

The trend in bulldozers has been to higher horsepower and heavier machines. The model shown, however, the Caterpillar D8, has been used for several years.

a paying proposition. In many instances, rail life has been tripled if the salvage work is carried on before rail wear is excessive. Steel pads are being regrozered, this procedure increasing pad life about 50 pct. Manganese pads have been in use for about a year and a half and have proved to be successful, although their initial cost is high, the life of this pad has justified the additional expense. These pads lend themselves well to regrozering. It is anticipated that these manganese pads will outlast the ordinary steel pad three to one.

Track-roller life is also being extended through salvage build up, with the submerged arc technique being used to bring these rollers back to standard size. The welding rod used in this process has hard facing characteristics, and a build-up roller will outlast the original. A few sets of manganese rails have been installed, and, to date, appear to have good possibilities for long life. These rails show a wear of about 1/16 in. after 1500 hours of operation. Manganese is also being used in the cutting edges and corners of the dozers, increasing the average life of the cutting edge by three or four times.

A few tractors have been equipped with a full centralized lubrication system. The primary pump being connected directly to the hydraulic dozer unit, so that everytime the dozer is operated, a predetermined quantity of grease is injected into each moving part. This insures the operator of adequate lubrication and eliminates the necessity of hand lubrication.

Drilling

The trend in drilling has been toward the 9-in. bits and a string of tools weighing 5500 lb. More attention is being given than ever before to the proper heat treatment of these larger bits. Some companies are installing electric heating furnaces. With such an installation, the bits can be brought up to heat for proper forging or quenching temperatures. This insures uniformity in bit hardness and strength.

The Quarrymaster, which was introduced a number of years ago, is still undergoing evolutionary changes. This machine now has a larger hammer and increased air-compressor capacity. Tungsten-carbide insert bits have been developed to the point where constant footage can be expected from each bit. Diesel power, both two and four cycle engines, has been replacing the gas engine on some of the older drills. Better performance and greater availability can be obtained through the use of Diesel power. Large auger drills are now being mounted on truck chassis to increase the flexibility. Although the auger drill does have drilling limitations, this machine working in the right kind of material does an acceptable job. Jet piercing is being used successfully in the new taconite operations.

An interesting innovation in exploration drilling tools is the development of the Brown-Madson core barrel and driver, which was designed to produce from soft ore, structure samples which would not be contaminated or disturbed in recovery. Thus, in addition to providing the usual chemical analyses, such samples also provide moisture, structure, and density data.

In operation, the core barrel is driven into virgin strata to the length of sample desired, usually 5 ft, and then withdrawn. The hole is then reamed with conventional churn-drill tools to the depth of the core barrel penetration, after which the cycle is repeated. The sample is retained in the inner liner and split for sample inspection and removal.

Road maintenance is becoming increasingly important. Although the heavy, tandem-axled trucks do tend to make and maintain good roads, tire costs are so high that constant road maintenance is imperative. Special heavy-duty graders designed for off-highway work in the mining industry have been introduced on the iron range in the last two years. These machines weigh considerably more than the standard contractor's model. They have proved a definite advantage for the heavy grading required around the mining areas. Cutting-edge thickness has been increased and, in some cases, manganese edges are being used. Most new graders are equipped with power steering. New serrated cutting edges are used to remove ice and snow during winter operation from the road surfaces. These blades have worked out satisfactorily, although their life is considerably shorter than the standard straight blade.

The difficulty in procuring replacement of parts has started a concerted salvage program by all the mining companies. Improved techniques and welding materials have created some salvage parts that are better than the original pieces.

GEOPHYSICS

plays more important part in search for subsurface information.

by LeRoy Scharon

EACH year it becomes apparent that geophysical activities in the fields of mining and engineering are increasing in the number and variety of applications. Many mining companies are including, as part of their exploration programs, geophysical surveys. The value of geophysics in highway and structural foundation investigations has been realized and is now an important part of subsurface investigations in conjunction with soil and rock borings.

United States of America

One of the major orebody discoveries of the year is that of the Grace mine near Morgantown in Berks County, Pa. This orebody, now under development by the Bethlehem Steel Co., was discovered by an airborne magnetometer survey carried out by the Aero Service Corp. of Philadelphia. The orebody, the geological occurrence of which is similar to those existing at Cornwall, Pa., was found at a depth of 1500 ft under a cover of Triassic sediments and is reported to have a reserve of well over 100 million tons. Shaft sinking and other construction work has started at the site.

Resistivity work was carried out at proposed dam sites in New York and in connection with the search for fluorspar veins in Kentucky. Spontaneous polarization investigations were pursued in the Appalachian region at various localities from North Carolina up into Virginia. This work was done in connection with the search for sulphide-bearing structures. Several indications were proven by subsequent drilling to correspond to unknown sulphide deposits, a few of these occurring in the vicinity of properties long under exploitation.

Refraction seismic methods applied to bedrock depth determinations as related to water problems on the Marquette Range and the extension of the regional gravity survey on the Menominee Range to learn the major structural features of the area have been reported by Lloyal O. Bacon. A gravity survey has been completed in the vicinity of Tioga, Bradford County, Pa., with a gravity profile being observed from Tioga east to the Delaware basin.

The Indiana Geological Survey is concerned with a state-wide gravity survey. Judson Mead, University of Indiana, reports that the bulk of the State Survey's geophysical work, however, has been "seismic refraction work in connection with drift thickness problems. The survey has made almost 1000 determinations in areas of moderately thick drift. The results of this work are of interest to both the coal mining industry and to the stone industry."

In the southeastern Missouri lead belt, magnetic, electrical resistivity, and electromagnetic applications for the discovery of new lead deposits have been used with success. A gravity survey of the residual-barite deposits in Washington County, Mo., was made during the summer season with preliminary computations of tonnages checking with tonnages mined.

Robert M. Dryer, of the University of Kansas has had considerable success in mapping structural features in southwestern Kansas with the gravity meter and is now engaged in tracing shoestring sands in eastern Kansas by resistivity surveys.

Several foundation sites were investigated in greater St. Louis using electrical resistivity and seismic refraction methods with success. A minimum amount of drilling data was available for checking and interpreting the geophysical results (Fig. 1).

It is to be noted that geophysical methods are finding a place in subsurface investigations for highway and foundation problems. Interest has been so keen in this field that the American Society for Testing Materials, at its annual meeting in June of this year, devoted one session of its symposium on surface and subsurface reconnaissance to geophysical papers involving the application of the electrical resistivity and seismic refraction methods to subsurface studies.

At least three major mining companies in the United States have entered the field recently in geochemistry. The program of research and development of geochemical techniques by the U. S. Geological Survey continues. Experimental field projects were conducted over lead-silver, cobalt, copper and zinc deposits in Idaho, Oregon, California, Wisconsin and Montana. Similar experiments were carried on by M. P. Nackowski in the Illinois-Kentucky fluorspar district and in the Tri-State Zinc district by R. Maurice Tripp with favorable results.

Geophysical activities of the U. S. Geological Survey for 1951 were extensive and varied. About 21,000 miles of airborne magnetic and 10,000 miles of airborne radioactivity traverse were flown in 1951 by the U. S. Geological Survey. A total of 35,000 miles of aeromagnetic traverse were compiled, 57 aeromagnetic maps were published and 14 preliminary maps were placed on open file.

Airborne surveys were made in Aroostook County, in the Katahdin and Dead River areas in Maine; in northwest Washington; over the Mother Lode district in California; in northeastern and northwestern Minnesota; and in the New York-New Jersey highlands. Of special interest were the surveys in Washington, where highly magnetic Eocene lavas gave information on structures in the overlying Miocene sedimentary rocks, and in northeastern Minnesota over the Duluth gabbro. The latter survey was made following the discovery of nickel-copper mineralization in the gabbro near its contact with the Virginia slate.

The principal ground geophysical surveys for metalliferous deposits and related purposes were made in the Colorado Plateau region, where electrical surveys assisted in prospecting; in Aroostook County, Maine, where ground magnetic surveys, following aeromagnetic surveys, have permitted tracing

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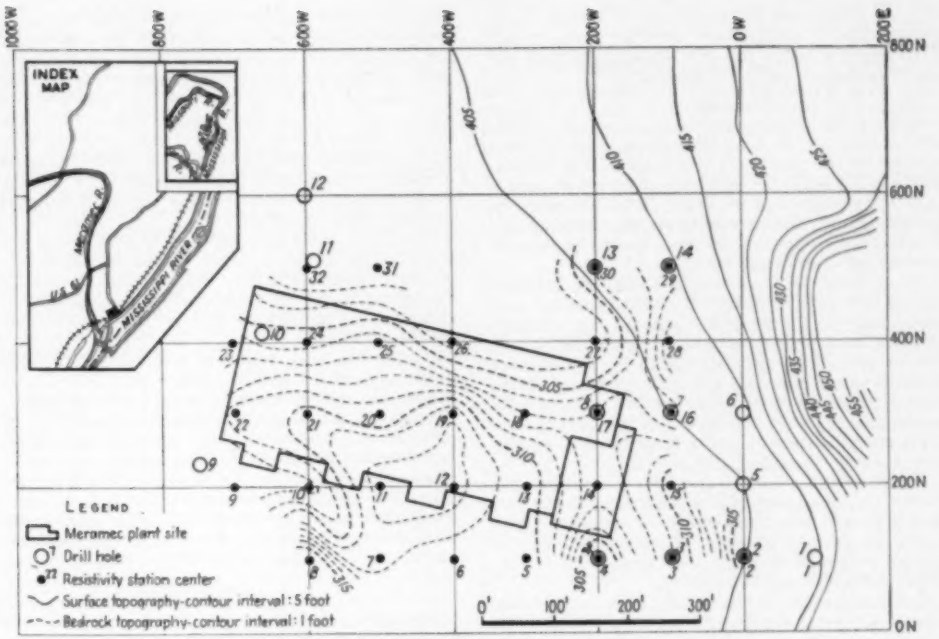

Fig. 1—Several foundation sites investigated in St. Louis using electrical resistivity and seismic refraction methods with success contoured bedrock contact. A minimum of drilling data, as shown above, was available for checking and interpreting the geophysical results.

magnetite-bearing manganese deposits underlying glacial drift; in the Tri-State district, where electrical resistivity surveys have been successful in outlining filled sinks and tracing fractured ground; in Riley County, Kansas, where magnetic surveys permitted outlining the extent of serpentine intrusions; and in the Fairbanks district, Alaska, where magnetic surveys were made to help trace replacement deposits of tungsten.

The Geological Survey has used geophysical methods with success in locating supplies of ground water. During 1951 ground water surveys, using either resistivity or seismic methods, were made in seven areas in Ohio, California, New York, and Idaho.

Shallow refraction surveys were also made in Massachusetts, in cooperation with the Massachusetts Department of Public Works to determine bedrock profiles along major highway locations.

Canada

Koulomzine, Geoffrey and Co. report that their activities, confined exclusively to mining geophysics, extended over 22 properties. Possibly their chief discovery was of zinc-lead-silver ore on the property of Mogador Mines Ltd., where a correlation of geophysical and glaciological studies was used.

Lundburg Explorations, Ltd., Toronto, reports that scintillation instruments, installed in an aeroplane, have been used to detect the presence of radioactive mineralization in the Charlebois Lake area, Saskatchewan, and the Colorado Plateau area in the United States. After considerable testing over well-known oil fields as the Redwater and Leduc in Alberta, the study of distribution of radioactive material in the vicinity of oil fields was conducted in Alberta, Saskatchewan, Texas and Nebraska.

During the year numerous electromagnetic surveys were made in the search for oil structures. In Montana and northern Alberta, areas were surveyed which had previously been mapped geologically and surveyed by seismic and gravity methods. The electromagnetic surveys confirmed the results of the previous examination and indicated the new method to be useful for rapid and inexpensive reconnaissance of large areas.

Sherwin Kelly reports that spontaneous polarization surveys were carried out in the Hazelton region of British Columbia in the search for lead-zinc-silver veins during which a number of electrical indications were obtained. The same type of surveys were carried out in western Quebec and eastern Ontario in the search for sulphide deposits. Resistivity investigations were made on about nine proposed dam sites in southwestern Ontario, for the purpose of determining depth to bedrock. Spontaneous polarization surveys were still in progress near the year's end in the Sioux Lookout area of western Ontario and in northern Saskatchewan.

Harry V. Warren of the University of British Columbia announces that the year 1951 may be thought of as the "coming of age" year of biogeochemistry in British Columbia. At least four major mining companies conducted intensive biogeochemical research programs involving close to 10,000 separate analyses. "Perhaps of greatest interest to the mining industry," reports Warren, " is a decision recently announced by the British Columbia Department of Mines to accept biogeochemical investiga-

tions for assessment work on more or less the same terms as geophysical surveys. This fact should result in an increase in the use of biogeochemistry in the search for ore in British Columbia."

Europe

Detailed airborne magnetic surveys were made over several of the magnetite deposits in northern Sweden by the Lundburg Explorations, Ltd. These flights were made at different altitudes to obtain data for calculation of the depth of the orebodies. In Iceland, Gunnar Bodvarsson has made successful applications of geophysical methods for the purpose of locating hot-water supplies.

Pierre Evrard, University of Liège, reports that for the first time in Belgium, a seismic survey was undertaken in the Belgian Campine coal district. The problem was to determine the horizontal extension of zones that are surrounded by sub-vertical faults of ante-Cretaceous age. Above these structures there is about 600 m of secondary and tertiary sediments. It is reported that results of this preliminary work were satisfactory and a more detailed survey will probably be made in the near future.

A note from L. Mintrop mentions the outstanding success in using geophysics underground in the discovery of unknown orebodies in old mines by shooting in the galleries of these old mines. This work is carried on by the Seismos Co. (Hannover) in different parts of western Germany.

The Compagnie Générale de Géophysique has created a special department working in the fields of mining, hydrology and civil engineering. Usually electrical methods are applied with the help of seismic refraction. The most important surveys made by this department that took place in France are mapping of faults in Alsace (Pechelbroon oil district), alluvial water surveys near Lyons and in Eastern France, and electrical and magnetic surveys for iron in Britanny.

G. Dessau in his discussion reveals that Italy has become quite geophysics conscious with considerable use being made of geophysical investigations in the field of oil, gas, and water. Resistivity work for gas was done in the provinces of Avellino, Benevento, Campobasso, and in the Piana di Catania. Telluric-current studies were made for oil and resistivity prospecting for water was done in the Puglie area. Seismic reflection surveys for oil were performed in the Lucania region, in the Crotone plain, in the Piana del Sele, in Taranto Province, in the Marche region and in the Oriental Po plain. In the volcanic area of Campi Flegrei near Naples, resistivity work was used in a search for hot gases and vapours to be utilized for geothermal energy. Electrical prospecting for natural steam at Larderello was highly successful. Natural potential prospecting surveys were made for pyrites near Pazzano.

The Director of the Institute Geologico y Minero de España, Josi Garcia Sineriz, reports that regional research surveys have been made with the gravity meter. He states that an important carboniferous bed was investigated by seismic methods of refraction at La Camocha. Many routes of underground water were discovered by electric direct-current and gravimetric methods.

Africa

The Compagnie Générale de Géophysique was active in French Morocco. In exploration for water, electrical prospecting (electrical sounding, resistivity maps) with the Schlumberger quadripole was the technique used. Such surveys included contouring an aquiferous limestone formation at depths up to 3000 ft, investigating depression of an impervious substratum in a coastal plain, and water supply investigations on three different airport sites for the U. S. Air Force. Exploration for oil included reflection seismic activities in the regions of Mehnes, Port-Lyautey, Petitjean, Sidi Yahia, and Sidi Berzouh; refraction seismic surveys in Djebel Branes; gravimetric and magnetic measurements in the Guereif desert; and telluric and electrical methods at Guerrouane, Djebel Branes.

Electrical methods were used in prospecting for water in the regions of Dekar, Conakrey, Zinder and in Mauritania in French West Africa. In French Equatorial Africa electrical surveys for mapping of structures in connection with prospecting for diamonds were made.

Geophysical and geological surveys are planned in the Central Congo Basin where magnetic, gravimetric and seismic methods will be used to determine the thickness of the loose sediments, Karroo or more recent, that have filled the depressions bordered by the Kasai and the Congo Basin curve.

Geophysical activities in Southern Rhodesia have consisted chiefly of the location of water by resistivity methods; however, self-potential surveys were carried out on the copper deposits of Rhodesia Copper Ventures, Ltd., northwest of Salisbury.

Asia and Australasia

Information on geophysical activities in India have been reported by M. B. Ramachandra Rao of the Geological Survey of India. Exploration for sulphides, manganese ores and investigations of bedrock problems in engineering projects constitute the major work. One party was also seeking structures connected with oil. Experimental magnetic surveys near Chaiborn were carried out for possible exploration of chromite. Magnetic surveys revealed four zones of strong magnetic indication in the alluvial covered area of the manganese belt near Ramtex. Magnetic surveys in the Balaghat district resulted in the discovery of numerous small manganese ore deposits at shallow depth. Magnetic and electrical surveys were carried out at a few of the ancient Baharagora workings in the Singhbhum copper belt. Shallow seismic-refraction and electrical-resistivity surveys were made for determining bedrock topography at Gaya and Nawada areas in Bihar State. A broad anticlinal structure has been indicated in Kathiawar, a western peninsular state, by magnetic and gravimetric surveys. Rao states that the outstanding development of the year was the first use of the airborne magnetometer on the Indian subcontinent. Aeromagnetic surveys are being made over the vast alluvial plain of Bengal and Assam to study structural anomalies worthy of investigation in the exploration for oil.

Considerable geophysical activity in Japan was reported by Kumiji Iida of the Geological Survey of Japan. The electrical method was applied to pyrite deposits in the Tochigi, Ooita and Hokkaido Prefectures; to copper deposits in the Wakayama prefecture; to kuro deposits in the Yamagata prefecture; to sulphur deposits in the Gumma prefecture; and to graphite deposits in the Toyama prefecture. Magnetic methods were used to discover new magnetite deposits at the Kamaishi mine in the Iwate Prefecture. Probably the most successful application was an off-shore seismic survey of the Ube coal field under the sea in the Yamaguchi Prefecture in the

western part of Honshu. Several geochemical surveys were made with the most successful application at the Kishi metal mine in the Wakayama Prefecture. Here soil analysis of zinc and copper were instrumental in aiding the interpretation of a spontaneous polarization survey.

From New Zealand, the report is that the major interest in applied geophysics is on the North Island in the Wairakei area. Since the area is limited in hydroelectric possibilities attention is being given to the generation of power from steam in the thermal field. J. Healy, New Zealand Geological Survey, reports that both geophysical and geochemical methods are being employed in the investigations. The entire volcanic region has been flown with the airborne magnetometer with gravimetric, seismic, thermometric electrical resistivity, and radioactivity data obtained on the ground.

South America

Geophysical applications, especially in the form of aeromagnetic surveys, are known to have been carried on in South America for both oil and metallic ore deposits; however, no report has been made.

Because of the portability of seismic equipment many areas are now being explored in the British West Indies. G. E. Higgins reports that such equipment has reduced the labor force by half and has allowed exploration for oil in terrain varying from swamps and rice paddies to hilly forests. Higgins states that the "main problems are interpretative. Very close co-ordination between the geological and geophysical sciences is an obvious necessity and, indeed, is practiced."

Schlumberger Well Surveying Corp. completed a surface exploration by telluric currents in the region of Lake Maracaibo.

Research and Developments

The increased activity of geophysics and its application to exploration of oil and mineral deposits and in engineering problems has led to continued research and new developments in instrumentation and field techniques.

The Pennsylvania State College has carried out extensive research in resistivity logging to determine how rock resistivity depends on composition, textural properties, and fluid content (Fig. 2). A new method of electrical measurements in drill holes has been developed by the Koulomzine, Geoffrey and Co. of Canada.

S. Dikes of the Colorado School of Mines has developed a technique for measuring residual strains in country rock adjacent to fissure fillings such as dikes and veins.

Fig. 2—Directional permeability cell and instrumentation developed at Penn State has given information on the relationship of rock resistivity to composition, textural properties, and fluid content.

The Schlumberger Well Surveying Corp. has introduced a new electrical logging method, called *Laterolog* which provides for better recording of formation resistivity. In this method a current is forced into the formation perpendicularly to the wall of the holes as a sheet of predetermined thickness with a special electrode arrangement and an automatic control system (Fig. 3).

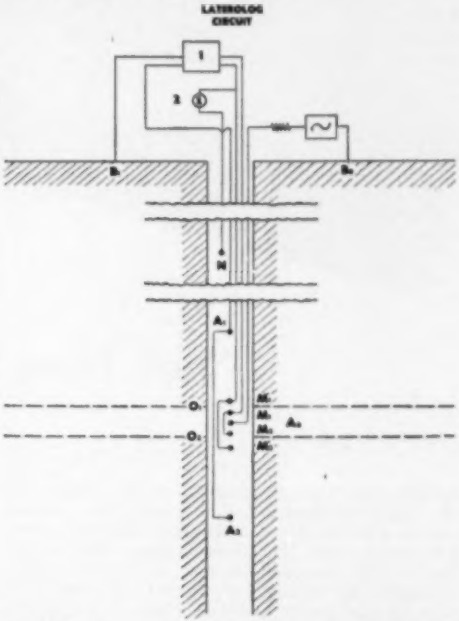

Fig. 3—Schlumberger Well's Laterolog records resistivity by special electrode arrangement and automatic controls which forces a current as a sheet of predetermined thickness perpendicular to hole wall.

A. W. Musgrave has developed an analog computer for the Colorado School of Mines Research Foundation comprised of a computer-drafter which will compute and draw, in a few hours, a wave-front chart for particular values of a and V_o for the velocity function $V = V_o + a\,T$.

C. A. Heiland reported that the Heiland Research Corp. has developed a Micro-Barometer and Micro-Barograph which should reduce considerably the time and expense in general elevation surveying in geophysical exploration.

The Illinois Survey, reports M. M. Leighton, made definite developments in geophysical instrumentation. For the past five years they have been exploring the relationship between radio-wave transmission at broadcast frequencies and geology. Preliminary results indicate that, under certain conditions, geologic situations influence the behaviour of the electromagnetic field. In cooperation with the Electronic Laboratories, Inc., of Indianapolis, Indiana, the Illinois Survey has developed a synchronous vibrator employed to replace the commutator on the Gish-Rooney-type, earth-resistivity instrument.

Possibly one of the most unique developments has been the practicability of airborne scintillation counters for radioactivity studies. It is reported that such counters are now being used by Lundburg Explorations, Ltd., and Aero Services, Ltd., of Toronto.

The Permian area of Carlsbad, N. Mex., was the scene of much activity in 1951, with the expansion of existing facilities and the construction of new plants for increased potash production. Duval Sulphur and Potash Co. has completed its two shafts, headframe installations, and the refinery is under construction.

Industrial Minerals Set New Production Records

by A. B. Cummins

THE past year has been of unusual interest for industrial minerals. It is increasingly evident that requirements for these raw materials move with general economic trends. Thus, with a peak year in the construction, chemical and petroleum industries, the nonmetallic mineral industries have been brought into the complex maze of an economy in which military spending is in the billions and in which the national income and wholesale commodity prices reached new levels. Many industrial minerals are of first rank essentiality in the defense effort and its supporting industries, and since some of these are of limited supply and others dependent on imports, the problems of procurement, distribution and conservation of available supplies make a complicated pattern.

Despite some drawbacks and weak spots, the industrial mineral industries have, in general, met the national situation with great credit and many new production records have been set. The general accomplishment in 1951 should be one of satisfaction with confidence for the future. Difficulties, unsolved problems and uncertainties should not obscure the general trend which many consider optimistic.

Prices in the main have been upward, in line with the inflation spiral, but nonmetallics appear with some exceptions to be behind the general increases. Labor difficulties have not been serious throughout the year. Retarding influences in expansions and planning have been the uncertainty of the Korean and international situations and a lack of confidence by many in the government economic program and its ultimate impact on the economic structure. It must also be kept in mind that stockpiling, unless all-out war develops, reaches a level and then ceases to be a major sustaining factor in the mineral markets.

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In accordance with the Defense Production Act of 1950 various control agencies have been set up to establish the desired rate of stockpile acquisitions. The objectives are subject to change depending on availabilities and needs—military, industrial, and civilian. In some minerals there has been disagreement on actual stockpile requirements, and there is some feeling that the needs of defense might be better met if more funds went into the development of new sources of supply of scarce raw materials and more materials were released to industry at this time.

Nonmetallic minerals on the strategic and critical list of the Munitions Board as of July 1951 were: Group I; asbestos, some types; bauxite, refractory grade; beryl; celestite; chromite, chemical and refractory grades; columbite; corundum; diamonds, industrial; fluorspar, acid grade; graphite, some types; kyanite; manganese ore, battery and chemical grades; mica, some types; quartz crystals; rare earths; sapphire and ruby; talc, steatite, block; and Group II; bauxite, abrasive; cryolite, natural; diamond dies; graphite, crystalline fines; iodine; mica, muscovite block, stained and lower; rutile; selenium; talc, steatite, ground; zirconium ore, zircon. Details on the current status of stockpiling inventories are not available.

The Defense Minerals Exploration Administration has, since April, executed 39 contracts for the exploration of nonmetallic minerals, including twenty for mica, seven for beryl-mica, six for asbestos, three for sulphur and one each for monazite, steatite talc and fluorspar. Total value of these contracts came to $892,059, of which the Government's participation amounts to $689,247. There were on hand at year's end another 97 applications for exploration aid on nonmetallic minerals in twenty different

states. Government aid for the exploration of strategic and critical minerals has been encouraged for prospects of indicated value.

The Revenue Act of 1951 gave the mining industry some tax relief. Section 319 of the Act grants percentage depletion to the following industrial minerals: 5 pct for sand gravel, slate, stone (including pumice and scoria), brick and tile clay, shale, oyster shell, clam shell, granite, marble, sodium chloride, and, if from brine wells, calcium chloride, magnesium chloride, and bromine; 10 pct for asbestos, brucite, dolomite, magnesite, perlite, wollastonite, calcium carbonates, and magnesium carbonates; 15 pct for borax, fuller's earth, tripoli, refractory and fire clay, quartzite, aplite, garnet, diatomaceous earth, and metallurgical and chemical grade limestone. Sulphur was raised from 15 pct to 23 pct.

Section 309 of the new Act provides that expenditures incurred in developing a mine, after existence of a commercial deposit has been disclosed, are deductible in the year incurred or, at the taxpayer's election may be deferred and charged off ratably against the ore benefited. It thus makes it clear that all such development expenditures are to be deducted from otherwise taxable income, independently of percentage depletion.

Section 342 provides that prospecting and exploration expenditures (up to $75,000 per year in any four years) prior to disclosure of a commercial deposit, may be charged off as expense, either currently or on a deferred basis. This provision, though limited in scope, will afford a measure of encouragement in the search for yet undiscovered deposits of much-needed minerals and in endeavors to disclose the commercial nature of mineral deposits.

Freight rate increases have now become one of the major factors in many of the industrial mineral industries. Since the war the Interstate Commerce Commission has authorized increased freight rates four times, the latest being Aug. 28, 1951, when increases of 9 pct were granted in the East, 6 pct in the South and West and 6 pct interterritorially, with some specified maximum increases as for ground rock phosphate and potash. These increases were added to the total freight charge whereas the previous authorizations were added to the freight rate. The carriers are now pressing the ICC to grant them the difference in the increase authorized and 15 pct which they originally requested. It is expected that the carriers will be granted their request, although nothing official has been released by the Commission. The trend of increased freight rates has created numerous problems in the nonmetallics field.

Commodity Listings

AGGREGATES AND GRANULES—The use of lightweight aggregates of many types—clays, shales, slags, pumice, diatomite, perlite, vermiculite, etc.—has been increasing rapidly. Facilities for production of aggregates are now quite widespread in most of the states. In Pennsylvania the demand continued strong, where three plants produce lightweight aggregate from blast furnace slag and one from coal wastes. In the West the lightweight aggregate field also is expanding, particularly with pumice and perlite. A large perlite operation is moving ahead at Socorro, N. Mex., and similar operations are scattered over parts of Arizona and California. Pumice is being mined in northern New Mexico, as well as in the Owens Valley area of California. The use of iron blast furnace slags as an industrial product has continued to increase. Approximately 75 pct of the slag produced in 1951 was processed into useful industrial products of one kind or another—especially structural lightweight aggregate and cements. The production of roofing granules has been at high levels approximating the phenomenal year 1950 (1,800,000 tons valued at $26.8 million).

ASBESTOS—Preliminary estimate of production of chrysotile in Canada was 925,000 tons for 1951 as compared with 834,491 tons for 1950. Despite this increase there was inadequate supply in most grades, although shorts were meeting requirements during the later months. The supply of spinning fiber was inadequate for industrial needs and stockpiling requirements are far from filled. Plans for the expansion of production facilities in Canada include a new mill at the Normandie mine of the Asbestos Corp. and a new shaft and mill at the Jeffrey mine of Johns-Manville. Imports of amosite, crocidolite, and Rhodesian chrysotile were less than desired. Stockpiles of amosite, Rhodesian chrysotile, and Arizona chrysotile are considerably below present objectives. Bolivian blue is being stockpiled for gas mask usage. Domestic production of short fiber in Vermont increased somewhat, and prices advanced for all grades. An increase in prices for Canadian fibers is anticipated early in 1952. Some shipment of low-iron asbestos, mostly of spinning quality, was made from Arizona. Efforts are being made by the individual operators and the government to increase this output. The Defense Minerals Exploration Administration has given support for six exploration contracts in four states. The deposit in the McDame Lake district of northern British Columbia is of interest but still unproved.

BARITE—Requirements increased during 1951 and the industry produced more ground barite than ever before for its largest use, oil well drilling. Chemical grade barite production exceeded 1950, reflecting the demand for more lithopone and barium chemicals. There was also a growing market for barite as a heavy aggregate for concrete used to coat natural gas transmitting pipe to give it weight and corrosion resistance for underwater and swamp crossings. Arkansas remained the largest source of ground barites for oil well drilling. Missouri is still first in the mining of chemical grade ore. Imports from Canada increased over 1950. Near Cartersville, Ga. some production of barite from old and large tailings deposits has continued.

BAUXITE—A big item in the bauxite industry has been the development of resources in Jamaica, which are reported to be the largest in the world. Imports of bauxite concentrates from Jamaica began in December. Most of the year's imports, however, were from the Guianas as formerly. The refractory and abrasive uses for bauxite have increased. Prices for all grades of bauxite were steady with moderate increases across the board. U. S. self-sufficiency for bauxite has decreased during recent years, but stockpiles are in favorable shape if the objectives are not increased. Much interest has been shown in the possibilities for development of bauxite resources in the Pacific Northwest. However, the reserves have not been adequately outlined and profitable operations apparently must be based on a joint iron and aluminum metal operation. During the year ALCOA built a new plant near Bauxite, Ark. for the processing of low grade bauxite ore. Completion of the Bureau of Mines experimental alumina plant at Laramie, Wyo. is expected.

BENTONITE—Production of bentonite in 1951 was probably over 1 million tons for the first time. It seems probable that the Wyoming-South Dakota district produced in 1951 more than 60 pct of the total. Over 90 pct of bentonite was used in oil well drilling, foundry sand bonding, and clarifying of oils. In 1951 drill-mud usage had by far the greatest gain in tonnage due to the heavy drilling programs in the oil fields and to the severe shortage of steel casing for drilling. Current

With the demand for beryllium alloys greatly increased, the new Harding mine, Taos County, N. Mex. has operated throughout 1951 to help alleviate the shortage. Shown is the portal of the tunnel that goes in just below the hanging-wall roll in a thick, nearly flat, pegmatite dike.

technical developments may lead to methods for well drilling which will not require casing, and if successful, this will greatly increase the demands for bentonite. Foundries, due to metal restrictions, probably used less bentonite in 1951. A recent scientific development is "organophilic bentonite," a natural Wyoming type chemically treated so that it thickens, swells and suspends in organic liquids.

BERYL—The demand for beryllium alloys needed for apparatus and equipment used by the armed forces has increased greatly and has placed beryl on the strategic list, with many restrictions on sales and uses. Domestic beryl has been mostly recovered by hand sorting in pegmatites. Production for 1951 is expected to approximate the record figure of 514 tons in 1950. South Dakota has been the principal producing area, followed by New Mexico and Colorado. The new Harding mine in Taos County, N. Mex., has been operated during all of 1951. Substantial quantities of fine grain beryl in certain U. S. pegmatites have been reported. Flotation fails to separate the beryl from the spodumene, etc. so other beneficiation methods are being developed and encouraged by DMPA as a part of the general pegmatite minerals program. Imports of beryl ore were indicated as about 4500 tons, most of this being received during the second half of the year when Brazil lifted its embargo. Imports were received also from Africa, India, and elsewhere. ECA was active during the year in rendering technical assistance aimed at development of critical foreign supplies. The prices for beryl concentrates advanced sharply during the year, up to 40 pct or more.

BORATE MINERALS—In 1950 output of all natural boron minerals approximated 647,000 tons. An increase of 10 to 20 pct is indicated for 1951. A large portion of the borates produced enter into the ceramic field and particularly in the vitreous enamels used largely in building. With probable decline in building, it is expected that the production trend of borax will be down. However, the use of boron for alloying with steel may somewhat overcome this lowering trend. Extensions were made to the boric acid plant of the Pacific Coast Borax Co. at Wilmington, Calif., thus increasing the boric acid manufacturing capacity in the U. S. by 10 or 15 pct. The Pacific Coast Borax Co. completed the sinking of two new shafts at Boron, Calif., and installed some Joy mechanical miners.

CARBON BLACK—Domestic demand for carbon black in 1951 has shown a continued shift to furnace types of black due to the predominant use of synthetic rubber. The use of furnace blacks increased 20 pct in 1951, while the use of channel blacks declined 23 pct. Stocks of both channel and furnace grades have increased throughout the year from their very low position at the beginning of 1951. Stocks of certain furnace grades, however, were still low at the end of the year in terms of days supply. Total demand for carbon black in 1951 was 1.6 billion lb, with an increase expected in 1952. All of the increased demand should be for furnace grades and more than sufficient capacity to cover this increase is already under construction. Most of the new construction in the U. S. is of furnace plants using oil as a feedstock. Such a plant is also under construction in Canada.

CEMENT—Production of portland cement in 1951 exceeded that of 1950 by 7 to 10 pct, approximating 245 million bbl. About 241 million bbl were shipped. Stocks at year's end were about 17 million. The annual capacity used by the industry was above 90 pct. There was an apparent tendency toward the end of the year for stocks of both finished cement and clinker to build up. Thus, at year's end NPA removed cement from restrictions on manufacturers' inventories. On the other hand, there were shortages in some districts.

A definite expansion in capacity amounting to 10 to 12 million bbl per year was completed or nearly completed in 1951. Total "potential capacity" is thus over 260 million bbl. A pronounced trend toward decentralization of the industry is noted; thus the major expansions have been in the South and to a lesser extent in the West. The expansion program should help to relieve some critical spot shortages. This expansion and decentralization has been by at least twelve companies. It has been estimated that the American cement industry has expanded more during the last two years than during the previous twenty years.

In the cement industry there is a definite trend toward the use of short grinding mills, closed circuited with air classifiers or separators and operated with high circulating loads. Several cement plants are now using spiral lined ball mills in their primary grinding circuit. Rapid development of pneumatic conveying and air blending systems for dry materials has occasioned a significant trend toward dry process cement.

CHROMITE—Chemical and refractory grades of chromite were in heavy demand. The total U. S. consumption of chromite in 1951 (the preliminary estimate was about 1.2 million tons) exceeded that of the previous record year of 1950. Total imports were up about 12 pct over 1950. All imports from Russia ceased, the major supplies coming from the Union of South Africa, Turkey, the Philippines, and Southern Rhodesia. The percentage usages of both refractory and chemical grades as compared with metallurgical grade increased in 1951 over 1950. A sharp price increase of about 25 pct was effected. Domestic production of chromite in 1951 is estimated to be about 2000 tons, nearly all of which was from Butte County, Calif. Efforts to stimulate greater production of chromite in the western states have not been too successful. Dissatisfaction with the GSA modification of the chrome purchase plan has been expressed by the Oregon Mining Association. In Turkey, prospecting for chrome ores is being actively carried on by the Eti Bank, and also by private interests. The Kavik mill of the Turk Meadin Co. has been treating about 200 tons of chrome ore per day.

CLAYS—In 1950 there were large increases in all classes of clay production and in ceramic products, particularly in heavy clay products. Plants operated at full capacity and there were many expansions. This high level of activity has continued throughout 1951. In December it appeared that 1950 records may not have been equaled in some fields, but will exceed those of 1949. The concensus of opinion is that if controls had not been in effect the clay industries in 1951 would have exceeded those of 1950 in practically all lines. Refractory clay deposits in the bauxite area of Arkansas have been shown to be of potential importance. There has been a steady increase in prospecting and development of new reserves of both kaolin and fullers earth in the Southeast.

Fullers earth continued the upward trend of the past ten years with more diversified markets and steady

prices. Major uses are in petroleum refining, industrial floor absorbent, insecticides, drilling muds, and vegetable oil refining. The principal production is still from Florida and Georgia. The Filtrol Corp. has engaged in the manufacture of a cracking catalyst for oil refining from a halloysite clay in Utah. Prospecting for further deposits in the Park City district of Utah has been active.

DIATOMITE—Production reached new record levels following the trend of recent years, but industry requirements were not fully met for some highly processed filter-aid grades. Additional production facilities by Johns-Manville and others should correct this condition in 1952. Diatomite has become recognized as one of the basic and important industrial minerals used as an almost indispensable tool in the chemical, food-processing and other industries. Fortunately, the United States' reserves of high quality diatomite are adequate for all requirements for many years to come.

FELDSPAR—Total production in 1951 has been estimated as a little less than for 1950. Principal uses have continued as in glass, pottery and enamels. North Carolina produced about 45 pct of domestic production; imports are small. Little change in prices over 1950 has been effected. The Carolina Mineral Co., subsidiary of the Consolidated Feldspar Corp., completed a new flotation plant at Spruce Pine, N. Car., to process 150 to 200 tons per day of alaskite ore. The Feldspar Flotation Corp. rebuilt its plant at Spruce Pine with capacity of processing about 4500 tons per month of mixed ore.

FLUORSPAR—The unprecedented demands of the steel and hydrofluoric acid industries, and heavy usages in glass and enamel hiked the U. S. consumption of fluorspar in 1951 to about one-half million tons. Domestic production and imports of high grade fluorspar failed to meet industrial and stockpile requirements despite record outputs and increased facilities. Existing mine and mill operations have been carried at full capacity. Imports from Mexico, Newfoundland and Germany exceeded 1950. Improvement in domestic output is assured by new fluorspar operations undertaken during the year or expected in 1952. Ozark-Mahoning has developed a mine and a new flotation plant at North Gate, Colo., to produce some 20,000 tons of acid grade concentrates per year. Operation is expected in 1952. Another operation by Ozark-Mahoning is near Deming, N. Mex. Fluorspar Mines, Inc. began production at its mill near Forney, Idaho. H. W. Gould is operating fluorspar deposits at Myer's Cave, Idaho, and Reynolds Metals Co. is producing from deposits near Salida, Colo. Penn Salt purchased two flotation mills near Marion, Kentucky. In addition, ALCOA is engaged in extensive development work in Illinois and Kentucky and increased the capacity of its flotation plant at Rosiclare, Ill. It also plans to reopen the old Good Hope mine.

Several steps were taken during the year to improve the fluorspar situation. NPA made allotments for the consumption in glass and enamel. The Office of Price Stabilization removed price controls on high grade ore. NPA is expected to limit consumption of hydrofluoric acid and take conservation measures on acid grade ore. DMPA has made agreements to pay $60 per ton for acid grade concentrates.

Upon abrogation of the reciprocal trade agreement between the U. S. and Mexico at the close of 1950, the duty on high grade fluorspar was lowered to $5 per ton and then to $1.875 per ton in June.

What may turn out to be a major discovery of fluorspar is a large area in northwest Coaxhuila, about 40 miles south of Boguillas, Mex. This was first reported about July 1951.

GEM MINERALS—Gem spodumene was discovered in three different pegmatite dikes in the Pala District of San Diego County, Calif. Some of the kunzite recovered is of exceptionally good color and high quality; value may amount to $90,000. The emerald mines of Muzo controlled by the Colombian government were reopened in January, 1951. The demand for diamonds in the U. S. exceeded one million carats per month. In general, the wholesale prices of gem diamonds increased about 15 pct in March 1951. Tests have indicated that colored diamonds of fine gem quality can be produced from ordinary gem stones by cyclotron bombardment; also that off-color stones may be rendered colorless. The results require confirmation.

GRAPHITE—Early in 1951 there was a critical shortage of flake graphite in the U. S. During the year consumers were able to obtain sufficient graphite for current needs as production in Madagascar increased and Government buying was eased. Prices increased steadily during the year and the ceilings established by the

Diatomite has reached new production levels, but requirements were not met for some highly processed grades. Additional facilities, such as the Johns-Manville plant at Lompoc, Calif. will be important in correcting this situation by late 1952.

Government resulted in a severe "squeeze" on some American processors. In August the Government exempted natural graphite, either as crude ore or concentrates, from price controls, and in December price controls were removed from foundry facings.

Domestic graphite mines are still in an unfavorable position with respect to competition from foreign sources but had little difficulty in selling their limited production. Texas has continued to supply the principal production of "fines" up to and including the very high grade lubricating quality. Other domestic producers planned to increase production with Government assistance. Consideration was also being given to reactivation of the Government-owned graphite mine at Chester Springs, Pa. The Bureau of Standards continued its study of domestic graphite for crucible manufacturing. Results indicate that some domestic material can be used in place of Madagascar flake graphite.

GYPSUM—The production of crude gypsum in 1951 exceeded the record of the previous year. Production of gypsum board, agricultural gypsum, building plasters, cement retarder and other major products were also at new highs. This has been the result of the increased expansion programs of 1950 and 1951 to meet increased building demands. In the U. S. in 1950 there were more than 51 calcining plants and 221 calcining units. No large new deposits in the U. S. were announced. Prices for calcined gypsum and most gypsum products advanced slightly in 1951. Michigan, New York, Texas, California, Iowa and Nevada have been the leading producers. In Canada its newest production has been by the Columbia Gypsum Products, Inc. near Windermere, B. C.

HEAT INSULATIONS—The demand for heat insulations follows closely the general industrial level particularly steel, new power installations, and manufacturing plants. The 1951 volume of production was high with only a slight drop in some lines. In magnesia insulations all the major producers effected changes in plants and processes resulting in improved products and greater production. The advent of new-type lime-silica insulations for the medium temperature field, 600° to 1200°F, was one of the important advances of the year.

Mineral, rock and glass wool products were produced at high levels for both building and industrial insulations. These materials have improved in quality steadily over the past few years and are available in forms suitable for various degrees of temperature service. Insulating and insulating-refractory brick have been in the greatest demand since the middle period of World War II. Some new types of unusually light-weight insulations for special military requirements have been developed.

LIME—Production of quick and hydrated lime in the U. S. during 1951 has been estimated as an all time high with a total production exceeding 7,800,000 tons. At the end of the year the entire lime industry was operating at approximately 100 pct of capacity. A number of producers (principally in the Pennsylvania and Missouri areas) have expanded their facilities with the addition of new kilns, quarry equipment, etc., to meet the increasing demand for lime products. Production costs increased during the year. While these have been reflected in higher prices, the general advance has fallen below the general price index.

Chemical application continues to dominate the end use of lime products over the time-honored applications in the building and agricultural fields. While it is estimated that 1,300,000 and 350,000 tons of lime were consumed during 1951 in the building and agricultural fields, respectively, consumption of chemical lime (excluding 1,850,000 tons of refractory lime dead-burned dolomite) probably will total nearly 4,300,000 tons. Statistics for 1951 probably will reveal that chemical lime usage in the major industries: metallurgical, paper, carbide, water purification, glass, and sewage and trade waste treatment, has increased in each. CaO consumption in the calcium carbide industry was estimated at over 700,000 tons. The Armour Research Foundation claims to have developed a procedure for preparing completely hydrated dolomitic lime and for controlling its plasticity—without employing the autoclave treatment now in use. The city of Miami, Fla., operates a rotary lime kiln to calcine sludge that accumulates from treatment of the municipal water supply.

LIMESTONE-DOLOMITE-MAGNESITE—Fluxstone for iron and steel manufacture, dead-burned dolomite, caustic, and dead-burned magnesite, has been in increasing demand paralleling the increase in steel production and general industrial activity.

While the demand has been increasing, the expansion program under DMPA stimulation was set up to meet requirement, and late in the year government assistance was no longer needed for limestone, fluxstone, other limestone (used in crushed or broken form as a filler in fertilizer and asphalt), dolomite, caustic lime, hydrated lime, dead-burned dolomite, caustic burned dolomite, magnesite, periclase and magnesium oxide.

In Pennsylvania the Standard Lime and Stone Co., Pleasant Gap, Centre County had under construction a new plant and underground mine which will go into operation about March 1, 1952. Fluxstone will be the principal product, but some agstone may be produced later .Other expansions of facilities in Pennsylvania were at H. E. Millard Co.'s Palmyra operation in the Annville high-calcium limestone belt. Whiterocks Quarries, Inc., Pleasant Gap, Centre County has doubled its plant capacity. G. & W. H. Corson, Inc., Plymouth Meeting, Montgomery County is expected to produce an additional 150,000 tons of dolomitic fluxstone annually.

There was considerable activity during the year in the search for very high grade calcite limestone suitable for making calcium carbide and for the exacting requirements for high grade, open hearth steel flux.

Additional facilities for the production of magnesite from sea water, brines, and dolomite will provide periclase for refractories, electrical insulators, also magnesium oxide and hydrate for chemical purposes. One company will use waste brines to produce a high grade magnesite along with by-products. Harbison-

With the demand for agstone rising, this relatively simple installation is producing a saleable product. This Dorrco Bowl Desilter is operated by G. & W. H. Corson, Inc. near Philadelphia, Pa.

Walker has announced that it has formed a subsidiary to develop magnesite deposits in Brazil. Basic Refractories Co. has started up operations at Gabbs, Nev., for the production of basic magnesite. Capacity is said to be 100,000 tons of refractory clinker per year.

LITHIUM MINERALS—The requirements for both lithium ores and lithium chemicals continued to rise rapidly during 1951 due to a number of military uses for lithium products and because lithium ores and chemicals were substituted for other industrial materials. For example, lithium products replaced much of the lead formerly used in optical glass, television tubes, glass tubing, porcelain enamel, and other types of ceramics. The military uses for lithium include aluminum welding fluxes, carbon dioxide absorbant, low-temperature dry batteries, and lubricating grease.

Foote Mineral Co. rehabilitated and enlarged the spodumene mines and concentrating mill near Kings Mountain, N. C., which will begin operations in July. Some tin is to be recovered from this operation. The Lithium Corp. constructed a new flotation concentrating mill in the Black Hills of North Dakota.

Despite the increased capacity for the production of lithium ores, no large increase in lithium chemical refining capacity was made during 1951. The importations of foreign lithium ores, mostly lepidolite, into the U. S. during 1951 were the largest on record. According to P. E. Landolt the 1946 to 1950 average annual demand for lithium products was 1.1 million pounds. As Li_2O, he estimated a potential industrial demand of 20 million pounds, requiring 100,000 tons of concentrates from 500,000 tons of mine-run ore.

MICA—has again been in the spotlight. As in the last war, the major supply of the better grades has been imported. While Indian muscovite splittings and Madagascar phlogopite supplies appear to be sufficient there is a short supply of condenser and block film grades. Despite increased prices for imported sheet micas, the quality in many cases has been unsatisfactory. The price increases as yet have not been sufficient to help domestic production significantly. In the U. S. the production of scrap and ground mica has stepped up appreciably. Improved methods of beneficiation and recovery have been developed and some important new uses appear promising. The General Electric Co. and others have been working on a mica "paper" made from scrap. A microfilm glass made from mica is under development by Corning. Westinghouse announced a new plastic mica three-coat corrosion resistant paint. The Mica Insulator Co. of Schenectady, N. Y. is working on a process for making electrical insulations from domestic mica scrap. DMEA executed 18 contracts for mica explorations in North Carolina, 2 in South Carolina and 6 joint mica-beryl explorations in South Dakota. Most of these are for rather small scale explorations. Progress has been made on the synthetic mica programs by the Bureau of Standards, the Bureau of Mines and the Colorado School of Mines.

SELENIUM—has assumed importance because of its use in rectifiers for military communication equipment and for stainless steel.

HAFNIUM—Early in 1951 the Foote Mineral Co. announced the first production of pure hafnium metal, an element with properties similar to zirconium. Hafnium is found in varying amounts in all zirconium ores.

COLUMBITE—The tremendous demand for columbium in special alloys and in certain grades of stainless steel caused columbite to rise to the top of the list of strategic minerals. The government attempted to increase the supply by encouraging new domestic and foreign production. U. S. production was increased late in the year when the Foote Mineral Co. began to recover less than one ton per month from pegmatites near Kings Mountain, N. C.

CARBON DIOXIDE—About 200 tons per day of carbon dioxide, mostly as dry ice, are being produced in California. The sources are the combustion of inflammable natural gas or oil, and from wells in Imperial and Mendocino Counties.

QUARTZ CRYSTAL—The demand for radio-grade quartz crystal is back. Some 2 to 3 million pounds per year are considered necessary for all-out war requirements. Stockpile acquisitions to date are far from the objectives but imports in 1951 were more than three times that of 1950. Prices for radio quartz crystal are well above those of the last war, but the quality of much material is lower.

STRONTIUM MINERALS—Industrial and stockpile requirements for celestite appear to have been met mostly by imports from England and Mexico. Domestic production was negligible, but new deposits are reported near Ludlow, Calif.

VERMICULITE—The usage of vermiculite, particularly in the building and insulations fields, continued on a firm basis. The Zonolite Co., the major producer, announced plans for a new and enlarged research laboratory at Evanston, Ill. Activities of the Vermiculite Association, Inc. have been broad and of much value to the industry.

Occurrences of vermiculite at Stanleyville in the Peth, Ont. area, found late in 1950, were explored by drilling and trenching. Initial optimism was tempered by further exploration.

WOLLASTONITE—Late in the year Godfrey Cabot of Boston took an operation option on the Willsboro Mining Co. deposit of wollastonite and diopside near Willsboro, Essex County, N. Y., and has started on the engineering for a production plant.

ZIRCON—The demand for zircon during 1951 was apparently the largest on record, but the supply was adequate, due primarily to increased production in Florida by the Humphrey Gold Mining Co. Substantial imports continued to come from Australia. The major present use is in the foundry sand field.

BITUMENS—Of native bitumens mined in the U. S., bituminous rock and gilsonite apparently maintained sales in 1951. A trend noted in 1950, however, was toward a fewer number of producers.

MONAZITE AND RARE EARTHS—The U. S. is believed to be potentially self-sufficient in rare-earth minerals. The bulk of monazite has been imported previously. India has placed in effect a virtual embargo, and it is becoming more and more difficult to get shipments from Brazil. It is highly probable that the U. S. Atomic Energy Commission may decide that it needs thorium. In that case, it is probable that monazite production might have to be greatly expanded to meet these requirements. A vigorous exploration program has uncovered large deposits of monazite in the Big Creek area near Cascade, Idaho. Presently there are three dredges in production on this placer. Florida is also producing the mineral as a co-product along with ilmenite, zircon, and rutile.

Spectacular discoveries in San Bernardino County, Calif., indicate the world's largest deposits of bastnasite. The latest finds are of rare-earth minerals in association with substantial tonnages of barite. In time this deposit undoubtedly will contribute significantly to the output of the rare-earth processing industry. This is an entirely new commercial source of the rare-earth metals, and will take time to develop satisfactory extraction processes.

The principal large-quantity uses of the rare-earth elements are in the form of fluorides and oxides for high-luminosity carbon arc electrodes and as metal in the pyrophoric alloy ferrocerium. Strategic uses of the rare-earth elements are limited to their application in military searchlights using carbon electrodes, aerial camera lenses, high speed glass and metal polishing, and phosphors. A new and potentially important application is in the development of cerium-magnesium alloys.

PEGMATITE PROGRAM—Great interest has been manifested in programs to develop pegmatite deposits in such manner that the recovery of strategic minerals therefrom may be accomplished economically. The DMPA has been active in this respect, and programs to increase the supply of beryl and muscovite mica

have been proposed. In the case of muscovite mica the problem seems to be that of obtaining the qualities and grades wanted for radio apparatus without opening the floodgates of the low quality and smaller sizes.

The essential feature of the pegmatite minerals program now under consideration by DMPA will be the establishment of buying stations in producing districts to encourage mining by affording miners an immediate cash market for the products of their mines. The minerals purchased can be allocated to the National Stockpile or can be reserved for industrial consumption. Beneficiation or processing may be undertaken by the buying agency if commercial resources or capacity prove inadequate.

The broad program for muscovite mica was given in a DMPA press release of December 14, 1951. Full details of the pegmatite minerals program are expected the early part of 1952.

POTASH—Deliveries of potash in North America by the five major American producers and three importers set an all-time high of approximately 1,650,000 tons K_2O in 1951. Domestic producers delivered approximately 1,400,000 tons K_2O of this total and imports were at their highest level since 1938.

During the year the Permian area at Carlsbad, N. Mex., was the scene of intense activity in construction and development work. Six companies were actively prospecting and three companies, the U. S. Potash Co., the Potash Co. of America, and the International Minerals and Chemicals Co., were expanding their capacities. The Potash Co. of America, after meeting difficulties with quicksand in sinking one of its shafts, resorted with success to the freezing methods in sinking its No. 5 shaft. The Duval Sulphur and Potash Co., a newcomer in this field, completed its two shafts and in November started its refinery. The Southwest Potash Co., another newcomer, is expected to reach the potash horizon early in 1952.

In March the Potash Co. of America started up its million dollar plant for the production of potassium sulphate-hydrochloric acid at Dumas, Tex. American Potash and Chemical Corp. produced KCl from brines in the Searles Lake region of California and Bonneville, Ltd. produced from brines at Wendover, Utah.

In the Carlsbad area several companies are experimenting with continuous mining and with the use of Jumbo assemblies. Roof bolting is also being utilized to improve roof support and to permit a high percentage of pillar extraction. The Potash Co. of America installed two Joy continuous mining machines.

In February 1951 the first permit for the exploration and development of potash in Canada was issued to Bala Petroleum Co., Ltd., for 100,000 acres in the Unity district in Saskatchewan. Possibilities for solution mining are being considered. No announcement has been received on plans for development of the potash deposits discovered in Yorkshire, England. These reserves are said to lie in the same geological structure as the German deposits. Imperial Chemical Ind., Ltd. is interested.

PHOSPHATE—Much progress was made in expansions in the phosphate industries. The demand for fertilizer grades increased, and requirements of the chemical industries went still higher.

In the West, new high levels of production were reached, particularly in elemental phosphorus. The Westvaco Chemical Division of Food Machinery and Chemical Corp. is constructing its fourth electrical furnace at Pocatello, Idaho. The Victor Chemicals Co. started production from its first furnace at Silver Bow, Mont., in November and the Monsanto Chemical Corp. is constructing its first furnace in the West at Soda Springs, Wyo.—this to be operating in 1952. Other companies are also putting in phosphate production facilities in the northwest. In all, there are 30 electric furnaces now producing or about ready to produce elemental phosphorus, and this will inevitably have a pronounced effect on the phosphate industries of the immediate future.

Activities in the New Mexico potash fields helped produce an all-time high of 1,650,000 tons of K_2O in 1951. These new flotation cells at the Potash Co. of America's plant at Carlsbad will add to the production in 1952.

Of much interest is the possible recovery of uranium values from some phosphate operations in Florida and in the western states. The Atomic Energy Commission is encouraging expansion of existing facilities and the construction of new wet-process phosphate plants from which uranium concentrates may be obtained as by-products.

REFRACTORIES—move in accord with general industrial activity, particularly with the metallurgical and steel industries. Thus there has been peak output of refractories in 1951. This has occasioned a heavy demand for refractory raw materials and various programs to alleviate shortages and improve quality are in action. There was further deterioration of the kyanite situation particularly that from India with supply becoming shorter and prices higher. Depletion of the diaspore deposits in Missouri continued at a rapid rate. Positive steps were taken to increase the supply of calcined South American bauxite of the type useful for high alumina refractories. New sources of raw material for the manufacture of silica brick were investigated and proven notably in Pennsylvania and Ohio. The pending depletion of the better grade flint clays for the manufacture of Super Duty Fireclay brick was given close attention.

The General Refractories Co. of Philadelphia is planning a highly modernized $3 million silica refractories manufacturing plant near Warren, Ohio.

Basic Refractories, Inc. of Cleveland has been expanding facilities to the extent of several million dollars for the production of granular dolomite and magnesite refractories at Nevada and Ohio operations.

In Pennsylvania some new developments and plant expansions have been a new plant for the production of silica brick at Morrisville, Pa., by General Refractories, also at Mount Union, the Harbison-Walker Co. is making extensive improvements to their crushing and grinding facilities to supplement the washing plant installed several years ago to upgrade silica rock for refractory uses, and the Harbison-Walker Company at Clearfield is expanding its fire brick plant.

SALT AND SALINES—No definite figures for salt production in 1951 are available, but a large increase over 1950 is indicated. This is particularly true of the salt of brine, and of rock salt. The production of these two types of salt is devoted chiefly to industrial uses. Evaporated salt held closer to the line of 1950.

Leading uses of salt in brine are soda ash and chlorine making. Requirements of salt for both of these increased in 1951, that for soda ash about 2 million tons and for chlorine about 1 million tons.

Increased capacity of various salt operations in New York, Michigan, Texas, California and Louisiana contributed to the general upswing in production to meet the various demands.

There was a peak in the refractories field output during 1951. Intense expansion and development have taken place with the Harbison-Walker Co. at Clearfield, Pa. expanding fire brick plant. The rotary kiln shown under construction is to be used for calcining clay aggregates used in refractory brick mixes.

In the brine field expansion of operations of nearly all of the producers of this type of salt for chemical making occurred. In Houston, Texas, the Texas Brine Corp. expanded its unique service of truck deliveries to local users.

Export trade in salt increased almost 300,000 tons in 1951.

A new development in eastern California is the discovery of a vast new deposit of salts beneath the surface of Searles Lake, in Inyo County.

Through a program of exploratory drilling the American Potash and Chemical Co. has outlined a vast tonnage of salines entirely beneath the deposit they are now working. The mineralogy of this new deposit is wholly different from that of the upper, shallower one. It is understood that the deeper deposit contains a high proportion of sodium carbonate. Control of this company has passed to the Mathieson Alkali Corp.

Westvaco is actively engaged in the construction of a new refinery for the production of soda ash from its Trona deposits at Westvaco, Wyo., but is delayed owing to difficulty in getting the required equipment. Prospecting to date has not defined the extent of the Trona deposit, but from indications it covers a large area.

Bromine, derived from sea water and natural brines, is in short supply due to greatly increased demands for production of aviation gasoline and other strategic uses. Production from sea water is being increased in Texas and from brines, mostly in the Michigan area.

SAND AND GRAVEL—Indications on the basis of new plant installations and demands from the construction industry are that a substantial increase of the order of 5 to 10 pct over 1950 will be shown for the total production of sand and gravel. The tremendous drain on reserves which these figures reflect has led to the necessity for discovering and developing new deposits. As a result, there has been increased application and refinement of established methods of prospecting as well as the adaptation of recent developments in this field. The seismic and electrical resistivity methods, particularly the latter, have been found adaptable to preliminary subsurface exploration for sand and gravel deposits and are being used in some areas.

The increased demand for sand and gravel has been accompanied by stricter requirements of the consumer for control of quality and grading. This has been particularly true of aggregates for use in concrete and bituminous mixtures which represent about 90 pct of sand and gravel consumption.

The stricter requirements for gradation has been met largely by the broader application of established techniques of screening, crushing, hydraulic classification and blending. Stricter limitations on the quality of aggregate particles themselves have in some cases necessitated the installation of equipment to reduce the quantity of so-called deleterious substances.

The expansion of the sand and gravel industry has brought additional problems quite unrelated to quality of product or the ability to meet demand with existing equipment and methods. These have to do principally with regulations covering zoning, land rehabilitation and stream pollution.

SILICA—All phases of industry utilizing highly purified silica sand or quartzitic materials were very active during 1951. Production of foundry and glass sand was so great that notable inroads were made on measured reserves. The industry is placing more and more emphasis on scientific exploration and increased efficiency in operations. The demand for ferrosilicon to be used in magnesium production has increased greatly and the search for suitable high-grade silicious gravel and massive quartzite is active. Expansion in acid open-hearth steel production has led to an increase in the demand for furnace bottom sand and for ganister to be used in acid-ramming mixtures and in the manufacture of high-refractory silica brick.

SLATE—markets in 1951 continued to be highly competitive but there was a marked increase in the sale of bulletin boards, toy slates and roofing slate.

In Pennsylvania two companies merged during 1951; one completed a new mill and another started a new mill to accommodate additional rock quarried from a new hole now in process of stripping of overburden. A roofing slate manufacturer completed modernization plans which included a conveyor belt delivery of material to the various operations.

A new type of slate roof was developed for ranch-type homes. This employs a mastic base instead of the conventional nailed-on-shingle.

The Pennsylvania State College conducted an operational analysis and time study of elemental operations used in the manufacture of slate products.

STONE—Crushed stone has had extended use during this past year in construction and maintenance work. Highway projects, such as the New Jersey Turnpike, used much stone. Military operations likewise have required a tremendous tonnage. There is growing use of granular sub-bases under concrete pavements, and densely graded crushed stone has been increasing in use for pavement base construction.

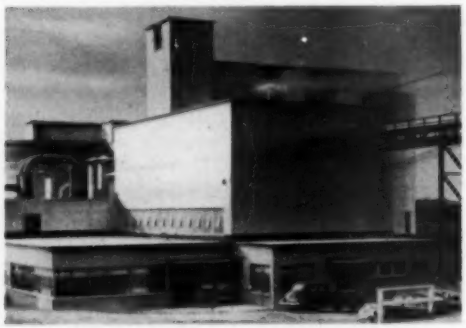
Some states have paid more attention to shape of crushed stone than formerly and, in consequence, some plants have installed special machinery for producing more cubical shape of particles. In Pennsylvania alone about $2 million was invested in 1951 for impact crushers and improved screens to provide better particle-shape control in the production of rock aggregate. Dry rotary drilling has been successfully adopted in at least three Pennsylvania quarries during the past year. Experience has indicated that one dry rotary can perform the work of about five conventional churn drills and give a straighter, smoother hole for blasting.

SULPHUR—has been perhaps the nation's most critical raw material in 1951. Tremendous interest has been shown by the press in providing continued publicity on all aspects of the situation. Despite the many controversies on the sulphur problem, great differences of opinion still exist. Because of the effort that has been made by the mining and chemical industries, the government and consumers to work out solutions, much progress has been made and the situation is now considerably clarified.

The case in brief is one where sudden and greatly increased need for a commodity which is essential to the highest degree for both civilian and military requirements, exceeds the current production capacity and in which the situation is complicated by international angles. The dependence of most foreign countries on U. S. sources has been greater than before the war. In England near panic conditions obtained during the spring, but IMC allocations have alleviated their shortage somewhat. At this time, according to

L. M. Williams, Jr., President of Freeport Sulphur Co., "sulphur stockpiles are at a minimum and must not be further reduced." NPA has now limited the sulphur inventories of uses to a 25-day supply. At the beginning of 1951 the Government began to allocate sulphur on a quarterly basis to all countries except Canada, and in June issued an order limiting domestic consumers to no more sulphur than they had used in 1950. Later in the year consumers by voluntary allocation restricted usage to about 80 pct of their 1950 consumption. It is understood that mandatory allocation orders may be effected early in 1952.

Many projects are being instituted in this country and abroad to alleviate the shortage. Of these projects, the first to go into production was the Starks dome mine in Louisiana. The next will probably be the Spindletop dome in Texas. Two others which will come into production possibly in two years are the Bay Ste. Elaine dome and the Garden Island Bay dome.



Trends for paint-grade talc have been in the direction of finer grinding. The new plant of the Gouverneur Talc Co. at Balmat, N. Y. has been one of the largest developments to produce this fine material, using 14 C. H. Wheeler fluid energy mills for superfine grinding of talc.

Other domestic projects may be expected to contribute significantly to the total, include a process for beneficiating low grade surface sulphur; various processes for recovering sulphur compounds from hydrocarbon gases (coke oven, natural and refinery gases); utilization of pyrites which, next to salt domes, constitute our greatest potential source of sulphur supply. More attention is being given to the production of sulphuric acid from smelter gases. There are also opportunities for recoveries from spent alkylation acid, oil refinery sludges and other industrial wastes.

In foreign countries efforts are also being made. These are no doubt stimulated by the fact that shipment of sulphur from the U. S. to foreign countries is now curtailed. It has been announced that a Frasch process plant will be built on the Isthmus of Tehuantepec. Various U. S. companies have embarked on extensive exploration programs for sulphur in Mexico, which many believe may in time become one of the world's top producers. Pemex is now producing about 150 tons per day at the Poza Rica fields. Canada proposes to develop pyrite deposits as sources of sulphur and sulphur compounds. Sour natural gas and smelter gas are getting attention also in that country.

In Spain, where production has fallen to about half of prewar figures, plans have been made to increase production from pyrite by the equivalent of 400,000 tons of sulphur during the next two years. The Italian Sulphur Corp. has plans to increase the output of their sulphur mines to 200,000 tons in 1952 and then to 450,000. The Italian Government is said to be helping.

Further steps taken in Europe, which may augment production of sulphur compounds are plants which utilize anhydrite in a combined cement-sulphuric acid process, and others which produce ammonium sulphate by double decomposition of calcium sulphate with ammonium carbonate. In March the British Government approved the erection of a plant to produce about 150,000 tons of acid per year from gypsum.

Opinion is much divided on the outcome of the sulphur shortage. It appears that the situation will be critical in the next few months, but that controls and conservation measures will then carry things along until production from the various sources under development and expansion materialize. Industry in general is optimistic in predicting a favorable world situation by 1953, but others consider 1955 more probable.

The price situation on sulphur has not been helpful. The moderate increases made do not appear to be in line with rising costs and inflation. Prices more in line with the law of supply and demand would do much to correct conditions, and to encourage investments.

TALC AND PYROPHYLLITE—Reports indicate that the production of New York State talc for 1951 will be approximately 5 pct under 1950. Demand for ceramic grades has been generally good throughout the industry and has accounted for a large portion of the consumption. Paint grade has lessened to some extent from the 1950 demand. Trends for paint grades of talc are in the direction of finer grinding, either by two-stage classification or fluid energy grinding. One of the largest developments in fluid energy grinding of talc ores is being performed at the Gouverneur Talc Co.'s mine and mill near Balmat, N. Y.

Talc mining is active in the desert country of southeastern California. Several large mines are being operated in the Death Valley country, and also in the south end of the Inyo Range, where talc of steatite grade is being produced.

Of great interest are the new mines being opened now in Montana. In 1951 the Sierra Talc and Clay Co. began an intensive prospecting, exploration and development program at its mine near Ennis, Madison County, Montana. Tests have revealed large deposits of high grade talc of steatite grade. This mine is expected to help substantially in the problem of short supply of steatite talc. A new milling plant is being built by Sierra Talc at Grand Island, Neb.

The 1951 demand for ground pyrophyllite has decreased somewhat from 1950. The ceramic demand has remained more or less stable, while the insecticide and rubber demand has decreased in volume. North Carolina leads all other states in production of pyrophyllite with California next.

TITANIUM MINERALS—Ilmenite production in the U. S. was estimated to be aboue 6 pct above 1950, the fifth consecutive annual increase. Imports added about 30 pct to the total. Domestic production of rutile, on the other hand, declined somewhat below 1950. Imports from Australia increased. Rutile was short at the end of the year since requirements for titanium metal, alloys and welding rod coatings had all stepped up. For the future it is claimed that sources of ilmenite and titanium dioxide slag from the Sorel, Que., operations as they reach full scale will give the U. S. an adsequate supply of raw material for years to come.

Titanium metal received a great deal of publicity and several new plants were constructed. The National Lead Co. and Du Pont continued to be the principal producers of the metal. Several other companies are now planning to get into this business. This year's production was about 700 tons and is expected to exceed 5000 tons in 1952.

Titanium raw materials were greatly helped by the continuous operation of the Du Pont facilities at Trail Ridge, Fla., the further development of the Sandford Lake titaniferous magnetite deposit by National Lead, and by operations in Virginia.

Nine companies are at present reported to be active in the Byron Bay area on the eastern Australian coast. As far as is known, all these concerns are handling beach sands. It is reported that there is a plant near Yokahama, Japan, which is treating beach sands and titaniferous slags and is turning out approximately 100 tons per month of titanium white.

COAL in 1951

Expanding coke and utility markets more than offset losses in the railroad and domestic markets. Mechanization proceeds apace.

by David R. Mitchell and R. M. Fleming

MANY trends were evident in the coal industry during 1951. Some were favorable for the industry; others were not. Probably those having the most far-reaching consequences are those affecting coal's markets. The rapid dieselization of many railroads and the continued trend toward oil and natural gas for home heating has caused serious dislocations in various mining districts. Mines have been forced to close down or to work on a reduced time basis. Conversely the increased activity in the metallurgical industries has increased the demand for coking and special purpose coals, and the growing production of electric energy has increased the demand in certain areas for steam coals. The increased demand for metallurgical coal and for steam raising by the large utilities is more than equal tonnagewise to the loss of coal to railroad dieselization and conversions to oil and gas in the domestic market.

Since much of the expansion is at captive mines of large corporations, many commercial operators supplying railroad and domestic users have had their markets curtailed without any compensating demand from other sources. Feverish activity was in evidence in many areas by commercial operators attempting to find new markets.

The Norfolk and Western Railway is the only major American railroad committed to the burning of coal. It has an exceptionally good cost record. During 1951, fifteen additional modern coal-burning steam switching locomotives were authorized for construction in the company's Roanoke shops at a cost of about $1,450,000. When the new order is completed the road will own a total of sixty locomotives of the modern-switcher type, including thirty acquired by purchase last year. The Norfolk and Western today is the only American railroad building its own motive power. All of these locomotives burn coal.

Production

Coal production in the year 1951 will approximate 570 million tons of anthracite, bituminous coal, and lignite. Of this, approximately 7 pct is anthracite. Total production is approximately 30 million tons more than in 1950 and reflects the increase in general industrial activity. Exports are expected to be close to 50 million tons. The industrial stockpile is close to 75 million tons, the highest it has been since 1943.

With the exception of the usual local stoppages the year 1951 was unmarked by labor disputes. It was a year of good labor-management relations with a negotiated wage increase unmarred by a work stoppage. This may be the beginning of an era of sensible negotiations to find agreeable settlements of disputes without the usual protracted bickering and industry-wide strike.

The United Mine Workers of America has condemned wildcat strikes, stating that in nearly every instance proper grievance procedures have not been instituted.

Government defense organizations, perhaps profiting by their experiences during World War II, are pursuing a more enlightened program with regard to the fuel requirements of the nation. Many prominent officials have stated that wherever possible coal should be considered the primary source of fuel in all defense expansion.

With the increased consumption of steel by defense projects, approval of transportation facilities for liquid and gaseous fuels have been refused where these fuels would enter a coal producing area. Liquid and gaseous fuel producers also have failed to provide satisfactory evidence that they have sufficient reserves and are capable of supplying their product in adequate amounts for the periods of time required.

Realization has at last become prevalent that the hydro-electric power installations in several areas are insufficient to handle increased demands. Steam generating plants are being constructed in these areas and equipped to burn coal. Most notable of these, is the TWA area whose supplemental steam power plants are expected to consume 10 million tons of coal per year when completed. The Pacific Northwest is another area which is expected to follow the same pattern.

Nearly all new steam-power generating plants are being equipped to burn coal either as a primary fuel or as an emergency measure.

Metallurgical Coal

The steel and other metallurgical industries are expanding rapidly to meet increased industrial demands and defense orders. Since these industries are dependent on coke, coke has had a year of high production and can be expected to break all existing records when steel-plant expansions are completed. Most notable of the expansion projects is that of the Delaware River area where the iron ore will be received by ship from Canada and South America. U. S. Steel is only one of several steel corporations that are planning on putting integrated steel producing units in this area.

The Defense Solids Fuels Administration announced in December that through November 30, 1951, 29 projects in eight states, with a total cost of

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about $48 million, have been approved under the accelerated tax amortization program for the increased production of metallurgical coal. The new projects will increase metallurgical coal capacity by an estimated 9,231,000 tons. DSFA Administrator Charles W. Connor stated: "The presently programmed expansion of the steel industry is expected to increase the demand for metallurgical coal to about 120 million tons by the end of 1952, an increase of about 17 million tons over the 1950 consumption rate."

Certificates of accelerated tax amortization have also been granted for 24 coke projects in fourteen states, to provide an estimated annual production increase of close to 4 million tons. These projects will cost an estimated $108 million. Mr. Connor estimated that the demand for coke is expected to reach about 84 million tons by June 1953, an increase of about 11,300,000 tons over the 1950 level.

Industrial and domestic consumers realized in the latter part of 1951 that the availability and low prices of natural gas and residual fuel oils then prevailing were due to the unloading of surplus inventories. Liquid fuels once again are competitive with coal and natural gas shortages have been predicted by several government officials. Many consumers are remembering the fuel oil shortage that occurred during the last emergency and are acting accordingly. Credit for enlightening the public and educating prospective consumers in the desirability of using coal and the advanced technology of its use must be given to the coal marketing organizations. Radio, television, and other means of communication have been used effectively for this purpose.

The coal by-product industry continues to prosper. Research and development of by-products continues at accelerated rates. Perhaps the largest item of interest in 1951 was the announcement by Secretary of Interior, Oscar L. Chapman, that the first privately financed plant for the hydrogenation of coal was being constructed at Institute, W. Va. This is an important step toward the commercial production of critical chemicals and synthetic petroleum products by the hydrogenation process. The plant is designed to process 300 tons of coal per day with provisions for physically handling double that input. It is an experimental pilot plant and will be used for research and development on different types of coal. Valuable technical knowledge of the coal hydrogenation process will be obtained that will be of great importance in the development of a synthetic liquid fuels industry which may be nearer than is realized.

The Pittsburgh Consolidation Coal Co. announced in the fall of 1951 that it was continuing basic research on coal as a raw material for the chemical industries. One million dollars has been appropriated for research and pilot-plant expenses at Library, Pa., on low-temperature carbonization followed by synthesis of the liquid and gaseous products. This approach is different from that of the Department of Interior's idea of complete liquifaction of the coal substance.

Pittsburgh Consolidation Coal Co. engineers argue that coal can be up-graded from its present value of about $5 a ton to approximately double this value. If necessary the process can be adapted to convert half or all the coal to liquid and gaseous products instead of the present 30 pct.

Mine Mechanization

All phases of bituminous coal mining continue to be mechanized at a rapid rate. Anthracite mechanization proceeds more slowly because of adverse natural conditions.

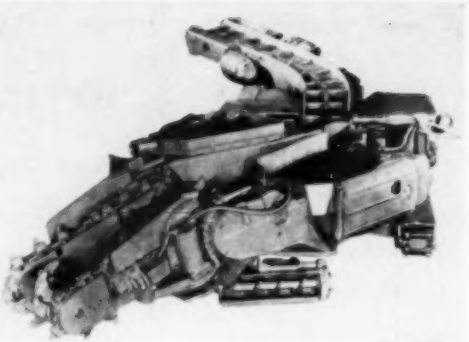


Fig. 1—The new rotary-driven head and larger teeth of the Joy continuous miner are designed to produce more lump and less fines.

Continuous machines combining the cutting, drilling, shooting and loading cycles have continued their expected expansion during 1951. In addition to the several machines available commercially, some new types are in active coal production and are being revised to correct the unpredictable weaknesses in initial machines of this type. Where mining and marketing conditions are amenable the continuous mining machines have affected considerable cost reductions.

The most widely used of these machines is the Joy. The latest models have a rotary-driven head as shown in Fig. 1. The new cutting head has larger teeth than formerly thus promoting increased lump and decrease of fine sizes.

At least one mine in southeastern Ohio is equipped 100 pct with continuous mining machines. Up to 40 tons per man-shift is reported as being obtained at this operation.

The adoption of continuous mining has brought other problems into sharp focus. Prominent among these are gathering haulage, roof control, and coal preparation.

Much experimentation is being done on transporting coal from continuous mining machines to the main haulage system. Shuttle cars and conveyors of various types are being tried. Extensible belt conveyors have been installed.

A newcomer to underground continuous mining during the year was the auger. Although used for several years to mine coal under the high wall at strip pits, 1951 witnessed the first extensive trials of these machines underground. Experiments show promise for mining thin seams with bad top conditions at low cost. Fig. 2 shows the auger sections of such a machine in operation in the No. 3 Elkhorn seam near Myra, Ky. This particular machine uses a cylindrical cutting head (lump head), as shown in the foreground, followed by standard auger sections, shown in the background. The driving mechanization is not shown.

At this mine the seam is 32 in. thick, and has a bad roof. Up to 30 tons per shift per face-man has been obtained, giving low costs in a seam that cannot be mined profitably by conventional methods.

The coal plow, which received extensive publicity following the war, is being tried. A German machine

Fig. 2—Continuous mining by augers first went underground in 1951 and shows promise in thin seams with bad top conditions.

is scheduled to go in a West Virginia mine and an English machine was placed in a Pennsylvania mine late in 1951.

Despite the success of continuous mining machines at various mines, it is becoming increasingly apparent that there are many seams where local and economic conditions prohibit their use. As a consequence there is renewed activity in improving existing loading machines and developing new models. Joy Manufacturing Co. has announced construction of a mining research center near Indiana, Pa., with a mine in which to test equipment as part of the project.

Roof control continues to occupy the attention of mine management and inspectors with considerable research on roof bolting. Arch Alexander, chief of the Department of Mines of W. Va., attributes the reduction in accidents from roof falls to the widespread practice of roof bolting in West Virginia. Currently roof falls account for 38 pct of the total number of fatal accidents as compared to more than 50 pct formerly.

The manufacturing companies are active in this field and several new machines for roof bolting are being tried. Fig. 3 shows a mobile auger-type drill and Fig. 4 a mobile air operated stoper. These machines permit a high degree of maneuverability and are self-propelled. The drill is swivel mounted so that holes can be put in at any angle.

The use of Airdox for blasting continues to grow. The development of small diameter cartridges has been particularly effective in permitting the mining of thin, friable seams without excessive degradation of the product. In such seams the percent of coarse sizes is greatly increased as compared to conventional blasting practices.

Preparation

A resurgence of preparation activity was apparent during the year, particularly at those mines preparing coal for the metallurgical coke industry.

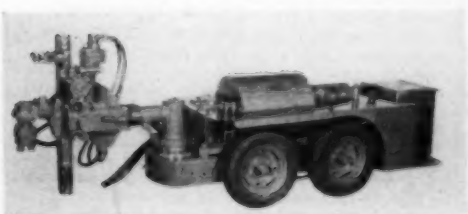
The Baum jig continues to be the most popular machine for mass cleaning of all sizes and for coarse coal cleaning. For difficult coals, dense-media processes using sand or magnetite for developing the medium were much in favor.

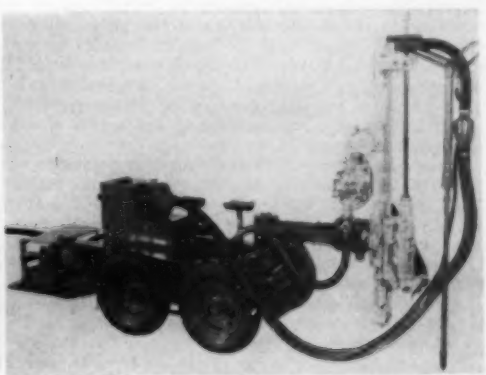
Probably, one of the most significant developments in magnetite dense-medium coal cleaning was the simplification of equipment and flow arrangement. Demonstrated on a plant basis during 1951, this appears to be a big step forward. Such an arrangement is shown in Fig. 5, where it is to be noted that the thickener and densifier have been eliminated. The equipment arrangement follows: 1—pre-wet screen, 2—rinse water spill box, 3—collecting hopper, 4—dense-medium separator, 5—fixed-drain screen, 6—rinse-water spill box, 7—drain-rinse screen, 8 and 9—collecting hoppers, 10—magnetic separator, 11—demagnetizing coil, 12—medium sump, 13—pump, 14—magnetizing coil, 15—wash-water desliming sump, 16—air cylinder for sump plug valve, 17—fresh-water inlet valve.

Percentage Depletion

The United States Revenue Bill of 1951, identified as HR4473, carried some provisions of special interest

Figs. 3 and 4—Mechanization for roof-bolting cycles is proceeding apace with development of mobile roof-drilling machines. Below is shown an augur-type drill and at the right is a stoper drill.





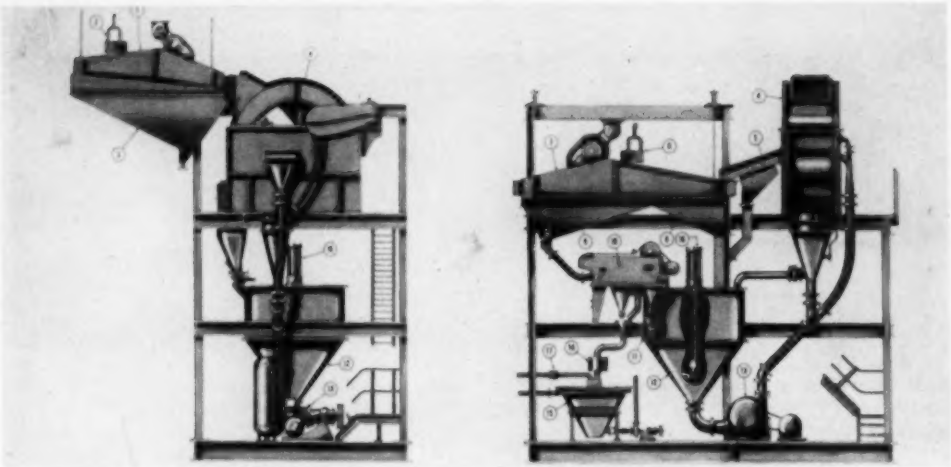


Fig. 5—Exemplifying the trend toward simplification of magnetite dense-medium coal-cleaning flow sheets is this plant where thickener and densifier have been eliminated.

to the coal industry. Since the combined, two directional onslaught of taxes and inflation on capital is approaching a danger point, any change in the situation becomes of vital interest not only to men who handle financial matters but to every individual engaged in any business having to do with a natural resource. HR4473 indicates, it is to be hoped, a realization on the part of members of Congress that it is vitally important to the national economy to keep the basic raw materials industries financially healthy. The new revenue law allows coal mining companies to increase the percentage depletion rate on coal mined from 5 to 10 pct of the gross income. Deductions for this item are limited to 50 pct of the net income.

Coal royalties are treated as capital gains. This provision is extended to cover lignite. However, the provision does not apply to income realized by an owner as a co-adventurer, partner or principal in the cutting of timber or mining coal. The amendment has no effect with respect to leasees.

Export Coal

During the fall, considerable activity developed towards increasing the export of coal to Great Britain, Europe, and Japan, particularly for coking. An interesting facet of this activity is the cooperative effort of the United Mine Workers of America with the operators to further the use of American coals in the export market. John L. Lewis' proposal of an industry-union shipping corporation to carry coal across the Atlantic or Pacific bears the marks of a constructive proposal.

Lewis in reporting to the UMWA policy committee on Dec. 19 in regard to the joint efforts of the coal operators and the UMWA to make sufficient coal available and at prices in competition with coal produced in iron-curtain countries stated:

"The present ocean rate from Hampton Roads is $14.50 per ton—with the price at European ports about $25 a ton which is too high a cost to be absorbed by the economy of the nations which are trying to regain their footing."

"Unfortunately, American taxpayers have to provide many dollars to buy coal mined behind the iron curtain."

"The price on U. S. coal marketed in Japan is $30.50; Russian coal is $20 a ton. There is no reason why American coal can not be sold there as cheap as Russian coal."

"We think Liberty ships should be allocated in sufficient numbers to a private enterprise which might be created to transport this coal from our ports at approximately cost of transport and that the government should carry the insurance on the bare bottoms."

"This would result in more employment, more sales, more railroad tonnage, and would save tax money."

Safety

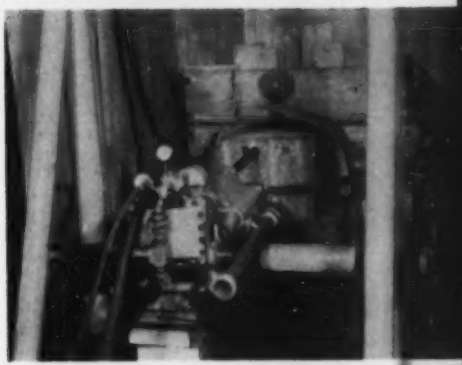
Despite the universal slogan "Safety First," too often it is "Safety Last" and that is true of this report of the industry for 1951. It is likely that a new safety record low will be established in 1951 in both the bituminous and anthracite industries. Fatality and non-fatality rates have been dropping at a consistent rate during the past ten years and preliminary reports indicate 1951 will be a good year in all states except Illinois.

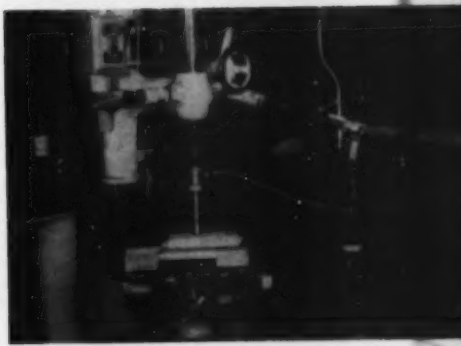
In Illinois, an otherwise good year, was abruptly terminated with a disastrous explosion at the New Orient mine of the Chicago, Wilmington, and Franklin Coal Co., West Frankfort, Ill., Friday night, Dec. 21; 119 miners lost their lives.

This was the worst mine disaster in Illinois since 1909 and the worst in the nation since 1928.

A Cooperative Venture Appreciated

This Annual Review issue of MINING ENGINEERING is in a true sense a joint report on the mineral industry by the individual members and committees of the Divisions of the Mining Branch of AIME. The authors of the articles have correlated the information for each article from sources too numerous to credit individually. At their instance, we do hereby join them in appreciation and acknowledgment for the splendid cooperation which has made this issue possible. The editors are also indebted for the excellent work of the authors in preparing these review articles.





Diamond Orientation In Drill Bits

by E. P. Pfleider

DIAMOND drill research work was initiated at the School of Mines, University of Minnesota, in late 1949. The Drilling Symposium held in Duluth that spring highlighted the problem of high cost and core recovery and the need for controlled testing. An advisory committee made up of informed representatives of both mining companies and drilling companies was formed to suggest and advise on a program of drill research.

A Hy-Mac hydraulic drill unit, see Fig. 1, especially designed for experimental testing, was obtained for this work by the School of Mines through the courtesy of the Carboloy Co. It is an extremely flexible unit, capable of exerting a forward thrust of about 1750 lb and turning at speeds from 650 to 2200 rpm. The feed arrangement is so designed that the advance can be set either at a constant rate or permitted to vary at a fixed pressure, see Fig. 2. The

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Discussion on this paper, TP 3228A, may be sent to AIME before March 31, 1952. Manuscript, July 9, 1951.

Fig. 1 — Hy-Mac hydraulic diamond drill unit with complete controls for experimental testing.

Fig. 2 — Hy-Mac diamond drill setup with (A) tachometer, (B) forward and reverse pressure gages, (C) water pressure gage, (D) flowmeter, (E) hydraulic pump pressure gage, and (F) strip for recording rate of advance.

Fig. 3 — Longyear Rotobore hydraulic research drill unit, instrumented same as Hy-Mac.

Fig. 4 — Laboratory drill using 1-in. OD core bit, drill press, and controlled pressure loading on bit.

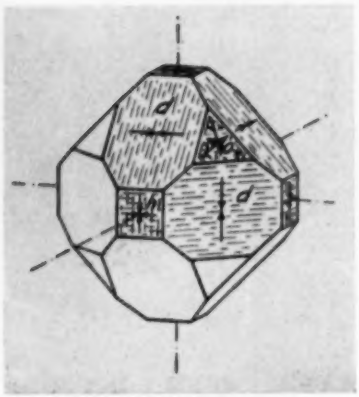


Fig. 5—Combination octahedron cube-dodecahedron crystal habits of the diamond.
After Kraus and Slawson.[1]

Fig. 7—Experimental drill bit No. M-4 having spiral pattern of diamond placement and negative rake (drag) orientation. Apparent rotation, counterclockwise.

drill is completely instrumented with a tachometer, A; forward and reverse pressure gages, B; water pressure gage, C; flowmeter, D; hydraulic pump pressure gage, E; and strip for recording rate of advance, F.

A second unit, a Longyear Rotobore hydraulic drill, see Fig. 3, was a gift to the school by the Oliver Iron Mining Co. This was overhauled completely through the kindness of the E. J. Longyear Co. and is now set up in a similar manner to the Hy-Mac. It is being used for research work in the problem of the cutting action of the diamond bit on various types of rocks. This project is sponsored by the U. S. Bureau of Mines through a graduate fellowship.

A small laboratory-size drill, see Fig. 4, cutting a ¾-in. core and powered by a drill press, also is used in conjunction with this fundamental study.

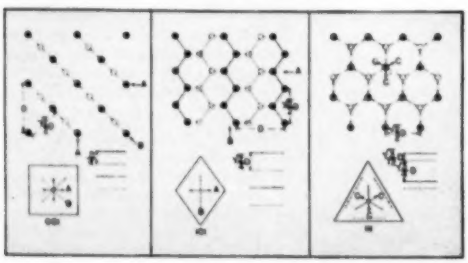
Most of the test work done to date has been in a coarse-grained, pink St. Cloud granite, from Cold Springs, Minn., donated by the Cold Springs Granite Co.

The committee decided that work should be of a fundamental nature, and the suggestion of determining the effect of the crystallographic orientation of the diamond in the bit was adopted as the first project. This paper is a progress report on the accomplishments to date.

The gem polisher and the wheel truer have known for many years that there is a great variation in hardness between the different crystal faces of the diamond. This characteristic has been used to good advantage in their work. Kraus and Slawson[1] have related the vector property of the crystal structure to the accepted cutting directions in the gem. Quantitative tests of a polishing operation in the watch industry have shown a ratio of 11,500 parts polished, using the hardest direction on the tris-octahedral face, to 200 parts using the softest direction on the cube or dodecahedral face.

Since there was a wealth of data on the characteristics of the individual diamond, it was decided to test immediately the effect of the orientation of a group of diamonds set in a bit. Messrs. Wing Agnew and Albert Long[2] of the Mount Weather Testing Station of the U. S. Bureau of Mines had initiated some previous work on orientation and assisted greatly in laying out the test procedures. The plan was to use a minimum number of stones in an EXT bit.

The writer visited the plant of the J. K. Smit Co. to observe the techniques in the manufacture of bits.



a b c

Fig. 6a—Diagrams showing (1) distribution of atoms in cube planes, (2) spacing of successive parallel planes, (3) optimum directions for polishing and sawing A, and (4) directions of greatest resistance, B.
b—Same for rhombic dodecahedron planes.
c—Same for octahedron planes. The three optimum polishing directions are indicated by C.
After Kraus and Slawson.[1]

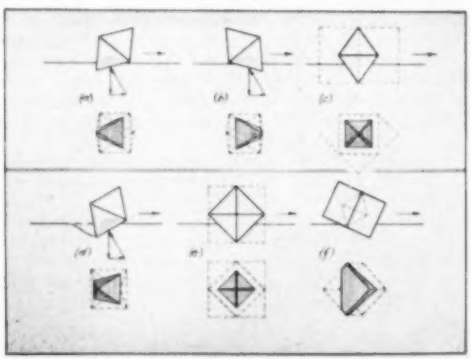


Fig. 8—Various crystallographic orientations of the octahedron diamond crystal tested in EXT core bits.

That company offered to furnish the molds and to manufacture the bits, without charge, as well as to sell the diamonds at cost.

Nine bits have been tested so far, and the results indicate a correlation between the fundamental knowledge of the crystallography of the diamond and the performance of the diamond in the drill bit. Much work remains to be done on different crystal forms and orientations.

Crystallography

The diamond crystallizes in a face-centered cubic lattice. The most common habit is the octahedron, eight faces. The diamond is found also in cubes, six faces, or rhombic dodecahedra, 12 faces, or in combination habits up to 48 faces. The model in Fig. 5 shows all of these planes. The diamond cutter refers to these planes as follows:

Plane	Crystallographic Name	Diamond Cutter	Directions For
100	cube	4-point	sawing-grinding
110	dodecahedron	2-point	sawing-grinding
111	octahedron	3-point	cleaving

The lines show the so-called *grain* and the arrows show the best cutting directions, the last mentioned being always parallel to an axis and perpendicular to the grain.

Cleavage is perfect on the octahedron face and somewhat less perfect on the dodecahedron face. Cleavage, while perfect, does not take place readily.

Kraus and Slawson[1] have made an intensive investigation of the crystallography of the diamond and have offered a theoretical explanation for the hardness variation and cleavage pattern based on the atomic structure. Fig. 6 shows the distribution of the atoms, the spacing of successive parallel planes, the optimum directions for polishing and sawing, and the directions of greatest resistance for the three planes under discussion.

A study of these diagrams reveals the following:

1—The atoms are most widely separated in the plane of the cube face; especially in the direction paralleling the crystallographic axes.

2—In the plane of the dodecahedral face the atoms are spaced more widely in the direction of the short diagonal than in the long diagonal.

3—The atoms are most closely packed in the plane of the octahedral face.

4—The computed number of effective valence bonds per atom between planes, considering two bonds lying in a plane to be equivalent to one additional effective bond, gives the following relationship:

cube	$4 \quad = 1$
rhombic dodecahedron	$4\sqrt{2} = 1.414$
octahedron (close spacing)	$4\sqrt{3} = 1.732$

5—The crystallographic axes intersect valence bonds at larger angles than do any other directions through the structure. Accordingly, those directions in which the atoms are most widely spaced, which have the smallest number of valence bonds, and which intersect those bonds at the greatest angles, can be expected to give the least resistance to cutting, polish, or wear. The full lines marked A on the cube face in Fig. 6a most closely fit these conditions; whereas the dashed lines shown on the octahedral face in Fig. 6c are the most remote. These facts would indicate that the experience of the diamond cutter and theory are well in agreement, namely, that the hardness should be greatest on the octahedral face, least on the cube, and intermediate on the rhombic dodecahedral.

Fig. 9—Bit M-5 having positive rake (gouge) orientation of diamonds.

Cleavage is perfect on the octahedral face, 111, and somewhat less perfect on the dodecahedral face. Again, the crystal structure provides an explanation. The atomic planes parallel to the octahedral face are not uniformly bonded. Alternate layers have weak and strong valence bonds. The cube planes are uniformly and strongly bonded. The layers in the dodecahedral plane are uniform, but intermediate in strength. The calculated relative number of bonds per atom for a unit area, D^2, in the various types of planes are:

	Bonds	*Ratio*
octahedral (wide spacing)	$4/3\sqrt{3}$	$= 1.00$
rhombic dodecahedral	$2\sqrt{2}$	$= 1.22$
cube	4	$= 1.73$
octahedral (close spacing)	$4\sqrt{3}$	$= 3.00$

Hardness Variation: Relative hardness of the various faces, based on an investigation by M. Tolkowsky, were reported by Drane[3] as follows:

Face	Easy Polishing Directions	Relative Max. Polishing Rates
Cubic face	2 and their reverses	0.82
Dodecahedral face	1 and its reverse	1.74
Octahedral face	3, polishing in reversed direction	0.14

Quantitative research work done by Winchell[4] for the Hamilton Watch Co. using the unidirectional rubbing of a flat diamond surface against stainless steel watch parts indicated a probable ratio of 100 to 1 for the hardness of the hardest direction on the hardest surface to the softest direction on the softest surface. The production obtained from the softest directions was less than 200 units, but the same tool, made with equivalent quality of diamond but so oriented to present the hardest direction and surface, consistently produced 20,000 units.

Slawson and Kahn[5] made an intensive study of the rate of polishing by lapping the stones in many directions. They found that, for practical purposes, the only surface directions that are impossible to

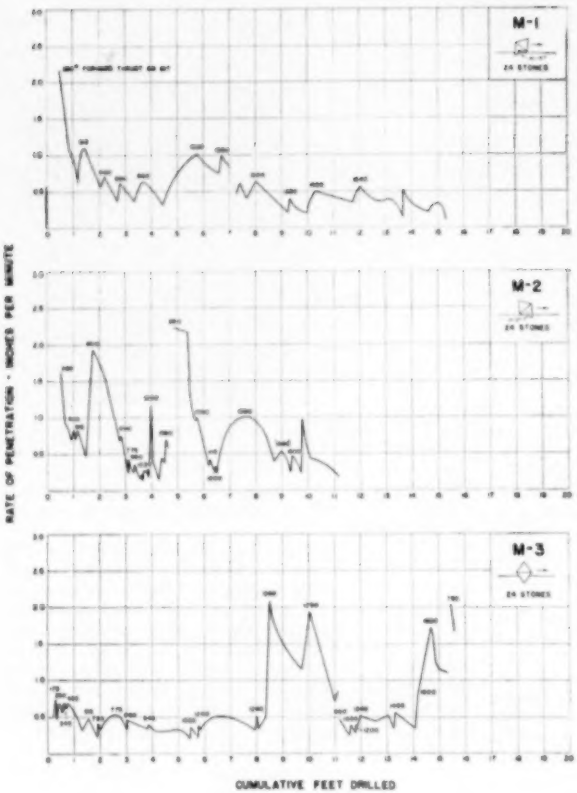


Fig. 10—Test history of EXT diamond drill bits M-1, M-2, and M-3. Constants: rpm of drill, 1000; gpm of water, 1.5. Variables: forward thrust of bit; rate of penetration.

polish are 1—any directions on a surface parallel to the octahedral face, 2—the dodecahedron parallel to the diagonal, and 3—the cube parallel to the diagonal.

The above work is not truly representative of conditions encountered in wheel truing[4] or diamond drilling, where vibration, shock, and tendency to cause fracture would mask the sole factor of hardness. It does, however, emphasize the importance of the relationship between hardness and orientation when independent of other conditions.

Orientation in the Bit

With the above-mentioned background of information from the investigators in other fields employing the industrial diamond, it was decided to proceed directly with the testing of diamond orientation in the bit. The smallest bit size, EXT, and a minimum number of diamonds, 20 in the crown and four kicker stones,* were chosen for the first set of three bits, with the thought that these conditions would reduce bit variables to a minimum and give the most accurate testing of the effect of diamond orientation. A diamond size of ten stones per carat was selected because of ease of discerning the crystal faces on this relatively large diamond. Admittedly, these stones are far too large for optimum results in granite. The diamonds were Best Grade Congos, all selected octahedrons and combination octahedron-dodecahedrons.

The blank molds for the bits were furnished by the J. K. Smit Co. After making the depressions in the blank mold to permit the necessary diamond exposure, the diamond was held in the mold at desired orientation by using a lacquer. The mold then was shipped back to the Smit Co. for bit manufacture. Powdered tungsten, or powdered iron, with a bonding alloy was used as the matrix material. A finished bit is shown in Fig. 7 in which the spiral pattern of diamond placement is evident. This pattern was used to insure full coverage of the crown. The bits had two waterways. Three different orientations were tested:

1—A *negative* rake off the octahedral face; i.e., where the apex or point of the octahedron trails the octahedral face along the lines of cutting action. This gives the effect of *dragging* the diamond to produce cutting action. See Figs. 8a and 8d. Bit M-4, having this type orientation, is shown in Fig. 7.

2—A positive rake off the octahedral face; i.e., where the apex or point of the octahedron is leading. This gives the effect of *plowing* or *gouging* with the diamond to produce cutting action, see Fig. 8b. Bit M-5, in Fig. 9, has this form of orientation.

3—*On point* of octahedron, with either the octa-

* Kicker stone is the trade term for those stones located on the inside and outside of the bit and employed to hold gage by reason of their reaming action.

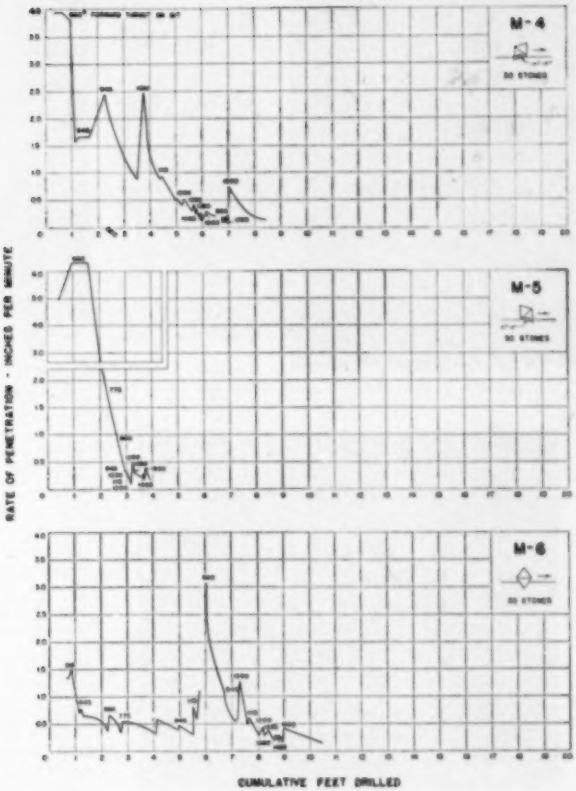


Fig. 11—Test history of EXT diamond drill. Bits M-4, M-5, and M-6. Constants: rpm of drill, 1000; gpm of water, 1.5. Variables: forward thrust of bit; rate of penetration.

hedral face or the dodecahedral face leading. Contact then is on a plane parallel to the cube face, either along the harder direction diagonal to the axes, or along the softest direction parallel to the crystallographic axes, see Figs. 8c and 8e.

Test Procedures

To obtain comparable data in testing the various bits, an attempt was made, insofar as possible, to hold the following conditions constant.

1—bit, except for diamond orientation; 2—rock type, St. Cloud *Pink* granite; 3—drill speed, 1000 rpm; 4—water, 1½ gpm, pressure varied as necessary to produce this flow; 5—force on bit, increased in increments of 10 psi (equivalent to approximately 90 lb thrust) whenever rate of penetration decreased to 50 pct the original rate obtained after applying the increment; and 6—terminal point of test, when penetration fell to 0.2 in. per min or, as in some cases, when gage was lost.

The comparable variables, then, for the various diamond orientations were the rate of penetration (in. per min) and the cumulative feet drilled.

After each run, averaging about 1½ ft, the diamonds were examined under a microscope to study the wear characteristics. Interesting conditions were photographed. It is felt that the correct interpretation of these microscopic observations is as important to the study as the comparison of actual footages drilled by the test drills.

The test results for the first two groups of experimental bits, consisting of three bits in each group, are presented in graph form in Figs. 10 and 11. Bits M-1 and M-4 have the negative rake orientation, 15° off the octahedral face, or otherwise expressed as a 15° drag angle. Bits M-2 and M-5 have a positive rake, approximately 15° off the octahedral face or a 15° gouge angle. Bits M-3 and M-6 are *on point* orientations, with the octahedral face leading.

Bit M-1 gave a very even performance, but continuous microscopic study of the individual diamonds throughout the life of the bit showed an early tendency toward polish. Diamond wear was extremely low. It is believed that these characteristics are typical of a low angle negative rake, since a large area of diamond is exposed to contact at an early stage. Furthermore, the orientation is structurally sound, since the pressure is somewhat normal to the cleavage plane, or the plane of weakness.

Bit M-4 was tested, after a short break in period, with an initial thrust of 860 lb, as contrasted with a starting force of 350 lb for Bit M-1. This increase was made with the dual purpose of determining the ability of the diamond in this orientation to withstand heavy starting loads, and whether large initial pressures would eliminate, or reduce, the tendency to polish. Results were disappointing in both respects.

Fig. 12—Bit M-1 (X8) with negative rake diamond orientation (15° drag angle), showing tendency of diamonds to polish after 2.8 ft drilling in granite. Rotation counterclockwise.

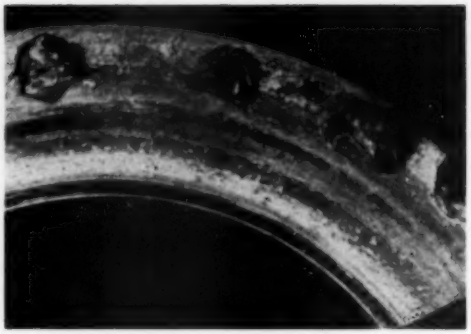


Fig. 14—Bit M-2 (X6) with positive rake diamond orientation (15° gauge angle) showing rough and fractured surfaces after 4.6 ft of drilling in granite.

Fig. 13—Bit M-1 (X3) showing polished flats after 13.6 ft of drilling in granite.

Bit M-2 proved to be a very erratic performer. The diamond with a positive rake can give abnormally high penetration rates but cannot withstand the shock loads. The diamonds break up early, probably along cleavage planes. The fragments remain in the bottom of the hole and accentuate the disintegration of the remaining stones. Diamond loss is high, as would be expected with a structurally weak orientation.

Bit M-5 has a positive rake and, similar to M-4, was tested at high starting pressures; although in this case the thrust was lowered to 690 lb in view of the experience with M-4. The initial rate of penetration was above 6 in. per min, but this fell off markedly. Large pieces of diamond were cleaved off, and these in turn accentuated the breakage of remaining stones to a point where advance was practically nil after but 4 ft of drilling.

Bit M-3 had the *on point* orientation with octahedral face leading, equivalent to cutting with the hardest direction of the cube face. Performance was poor for the first 8 ft, during which time the points were wearing down to form flat surfaces. After 8 ft the rate of penetration increased immediately from 0.5 to 2.2 in. per min. There are two possible explanations for this: 1—that the critical force necessary to cause penetration of the diamonds into the rock was reached, or 2—that the points of the few diamonds used in the crown of the bit did not completely sweep the surface to be drilled until they had worn considerably. In any event, results thereafter were erratic, and the bit failed to advance after drilling 15.6 ft because of binding in the hole caused by lack of gage. As previously mentioned, the diamond points wear down rapidly and then form large square polished surfaces, which require high pressures to effect their impression into the rock surface.

Bit M-6 was set with *random* orientation by a person knowing nothing of crystallography. Examination of the bit after manufacture showed that 16 out of the 26 crown diamonds had on point orientation. Apparently, this is the natural and easy method of setting. The bit reacted much like M-3, which it resembles.

Figs. 12 through 16 are micrographs showing some of the diamond wear characteristics described in the test results of Bits M-1 to M-6. When studying these photographs, it is important to bear in mind that the direction of rotation of the bit, when drilling, would be counterclockwise. Fig. 12 is of Bit M-1 (negative rake), and the tendency to polish is seen after but 2.8 ft of advance. Fig. 13 shows the condition accentuated after 13.6 ft drilled. Parts of Bit M-2, after 4.6 ft, and Bit M-5, after 3.96 ft total, both having positive rake orientation, are shown in Figs. 14 and 15. It can be seen that the diamond surfaces are rough, resulting in fast initial penetration. However, the diamonds have parted along cleavage planes, ruining other stones and even gouging into matrix, as evident in the photograph of M-5. Fig. 16 shows Bit M-3, on point orientation, after 9.7 ft drilled. The flat square surfaces resisting penetration are evident.

The cumulative results of Bits M-1 to M-6, including their diamond loss data, are presented in Figs. 17 and 18. Generally the bits with negative orientation gave the best results after considering that M-4 had an excessive starting pressure on the bit. Bit M-1 had an abnormally low diamond loss of 0.0124 carats per ft, which was 40 pct of that for M-3, the next lowest. Positive rake bits are characterized by high initial penetration rates, low total footages, and large diamond loss. Bits with on point and random, 60 pct on point, orientations gave low

Fig. 15—Bit M-5 (X5) with positive rake (15° gouge angle), showing fractured diamonds and gouged matrix after 3.9 ft of drilling in granite.

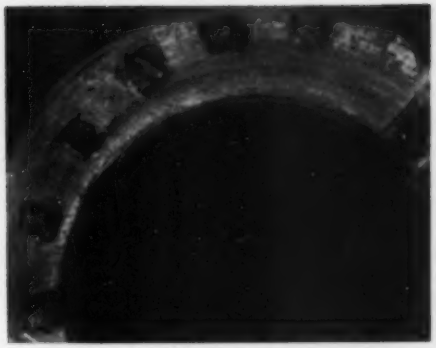
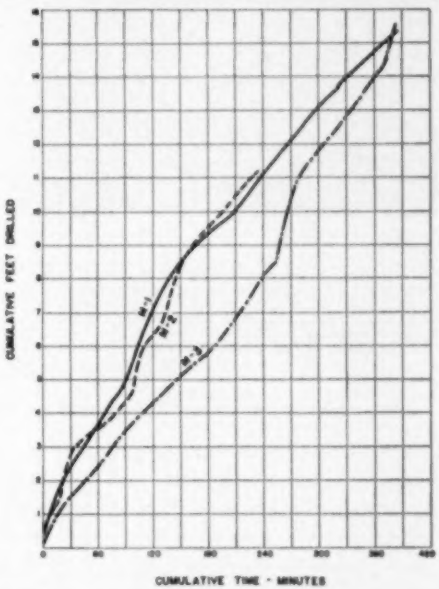


Fig. 16—Bit M-3 (X4) with on point orientation of diamond, showing flat square surfaces resisting penetration after 9.7 ft of drilling in granite.

EXT Bits		M-1		M-2		M-3	
Diamond	Type	Congo - Octahedron and Combination Octahedron-Dodecahedron					
	Size	10 per Carat					
	Number	24 Stones (20 Crown; 4 "Kicker")					
Matrix		Powdered Tungsten — Bonding Alloy					
Diamond Orientation and Exposure		Negative Rake-15° Oct. Face		Positive Rake-15° Oct. Face		Cube Face on Oct. Point	
Ft drilled		15.32		11.16		15.61	
Diamond weights		Carats					
Original		2.75	2.75	2.79	2.79	2.79	2.79
Final		2.56		2.32		2.33	
Salvage (reusable)			2.56		2.17		2.33
Diamond loss		Carats					
Net from wear		0.19		0.47		0.46	
Total—after salvage			0.19		0.62		0.46
		Carats per Ft					
Net from wear		0.0124		0.0422		0.0294	
Total—after salvage			0.0124		0.0558		0.0294

Fig. 17—Cumulative test data, bits M-1, M-2, and M-3.



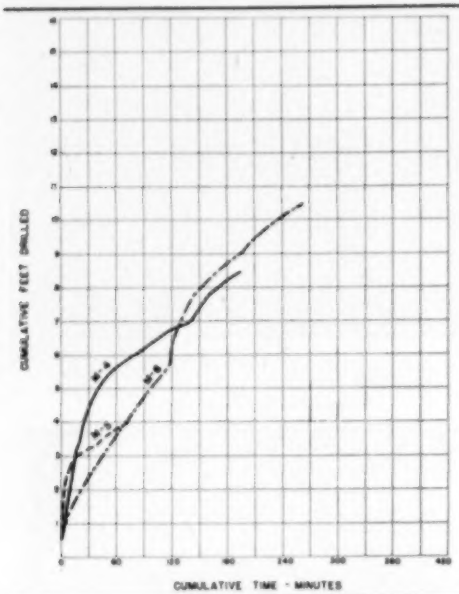
starting rates, with short lived highs in midlife, and intermediate footages and diamond loss.

The effect of high initial starting pressures on the bit, as used for Bits M-4, M-5 and M-6, is readily evident when comparing the results of these bits with the first three bits. This is particularly true when taking into consideration the fact that the last group had 26 crown stones per bit, whereas the first group had but 20. Total footage for Bits M-1, M-2 and M-3 was 42.1 ft; for Bits M-4, M-5 and M-6, 22.8 ft. A comparison of total diamond wear per foot shows 0.031 carats per ft for the first three bits to 0.081 carats per ft for the last three bits.

Net diamond loss from wear was determined by subtracting the weight of all diamond recovered at the end of the test from the original weight of diamond set in the bit. Total diamond loss was calculated by adding to the wear loss the weight of any recovered diamonds that were rejected for further use because of their small size or fractured condition.

On the basis of experience with the first six bits, it was decided to compare further the negative rake as against the on point setting. It was felt that the early tendency to polish on the negative rake could be diminished by a compromise with diamond loss. Hence, the drag angle was increased to 30° for Bit M-7. It was desired also to test one bit having on point setting with the dodecahedron face leading, to see if this change would make any appreciable difference over that of the on point setting with the octahedral face leading.

The test results of Bit M-7, see Fig. 19, tend to prove the correctness of the reasoning in increasing the rake to 30°. The individual diamonds held up well, and the polishing effect was reduced greatly



EXT Bits		M-4		M-5		M-6	
Diamond	Type	Congo - Octahedron and Combination Octahedron-Dodecahedron					
	Size	10 per Carat					
	Number	30 Stones (26 Crown; 4 "Kicker")					
Matrix		Powdered Tungsten — Bonding Alloy					
Diamond Orientation and Exposure		Negative Rake-15° Oct. Face		Positive Rake-15° Oct. Face		Random-65 Pct of Stones on Oct. Point	
Ft drilled		8.45		3.96		10.47	
Diamond weights		Carats					
Original		3.30	3.30	3.25	3.25	3.34	3.34
Final		2.65		2.91		2.38	
Salvage (reusable)			2.57		2.85		2.63
Diamond loss		Carats					
Net from wear		0.65		0.34		0.66	
Total—after salvage			0.73		0.40		0.71
		Carats per Ft					
Net from wear		0.0769		0.0858		0.0630	
Total—after salvage			0.0864		0.1010		0.0678

Fig. 18—Cumulative test data, bits M-4, M-5, and M-6.

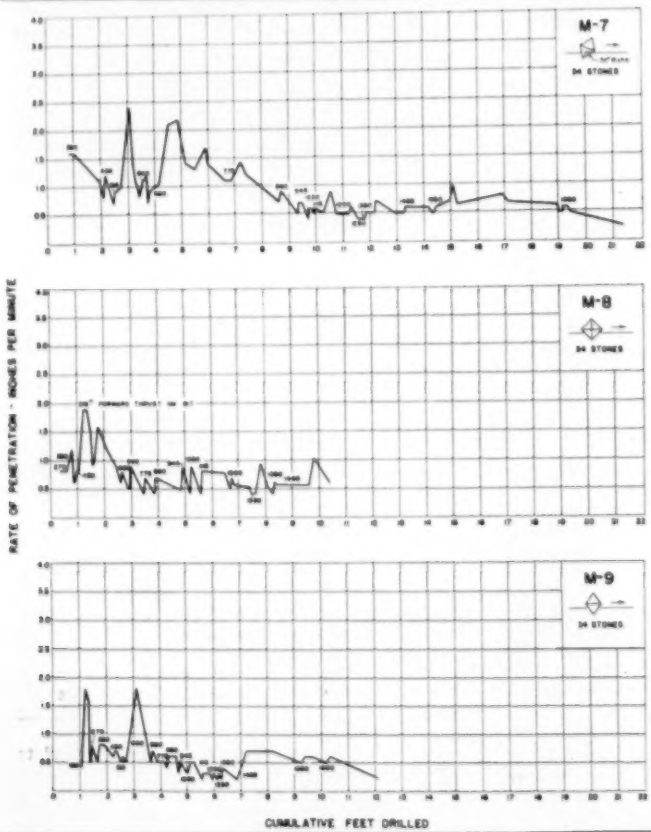


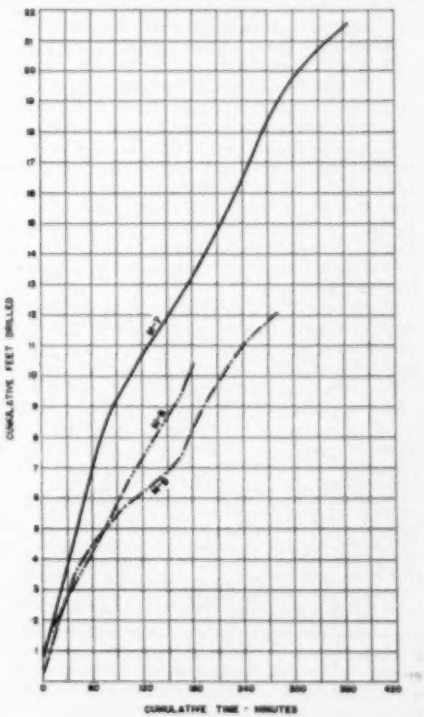
Fig. 19—Test history of EXT diamond drill bits M-7, M-8, and M-9. Constants: rpm of drill, 1000; gpm of water, 1.5. Variables: forward thrust of bit; rate of penetration.

Fig. 20 (above)—Bit M-7 (X5) with negative rake diamond orientation (30° drag angle), showing tendency of trailing edge of octahedron to break away and leave rough surface on diamonds after 9.9 ft of drilling in granite.

Fig. 21 (below)—Bit M-8 (X4) with on point diamond orientation, dodecahedral face leading, showing polished flats and star-shaped fracture patterns after 6.2 ft of drilling in granite.

EXT Bits		M-7		M-8		M-9	
Diamond	Type	Congo - Octahedron and Combination Octahedron-Dodecahedron					
	Size	10 per Carat					
	Number	34 Stones (26 Crown; 8 "Kicker")					
Matrix		Iron Powder — Eutectic Bonding					
Diamond Orientation and Exposure		Negative Rake-30° Oct. Face		Cube Face on Oct. Point		Cube Face on Oct. Point	
Ft drilled		21.33		10.38		12.03	
Diamond weights		Carats					
Original		3.70	3.70	3.95	3.95	3.57	3.57
Final		3.15		3.46		2.78	
Salvage (reusable)			3.05		3.41		2.64
Diamond loss		Carats					
Net from wear		0.55		0.49		0.79	
Total—after salvage			0.65		0.54		0.93
		Carats per Ft					
Net from wear		0.0256		0.0472		0.0657	
Total—after salvage			0.0302		0.0544		0.0773

Fig. 22—Cumulative test data, bits M-7, M-8, and M-9.



since the exposed face would fracture just enough to produce a rough surface. This effect gave a 50 pct increase in footage drilled and a 100 pct improvement in average rate of penetration over Bit M-1.

Bits M-8 and M-9 reacted much the same as the other on point orientations after taking into consideration that these bits had ten more diamonds than M-3 and four more than M-6. There was little noticeable difference in the performance of M-8, having the dodecahedral face leading, as compared to M-9, with the octahedral face leading. Both bits reacted remarkably the same.

Fig. 20 shows Bit M-7, 30° negative rake, after drilling 9.9 ft. The stones are still rough, apparently due to the breaking away of the trailing edge. Some consideration has been given to supporting this *trailing* edge with matrix material to decrease breakage and diamond loss. However, this practice might accentuate the polishing effect.

Fig. 21 is of Bit M-8, on point orientation, dodecahedral face leading, after 6.2 ft of advance. The stones are beginning to form polished flats. Several of the diamonds exhibited peculiar star-shaped fracture patterns, possibly caused by breakage along the four cleavage planes paralleling the octahedral face. This is indicated clearly in the third and fourth stones from the left.

The cumulative results of Bits M-7, M-8 and M-9 are presented in Fig. 22. It is evident that M-7 gave much the best performance of all nine bits. A comparison of Bit M-7 to Bits M-8 and M-9 shows double the total advance, double the drilling speed, and half the diamond loss.

Summary

Five different orientations of the octahedron, or combination octahedron-dodecahedron, diamond crystals have been tested to date in EXT diamond core bits. These are illustrated by Figs. 8a through 8e. The results and evaluation for each of these five orientations might be summarized as follows:

1—The low-angle negative rake is a structurally strong orientation, since the resultant reaction is approximately normal to the octahedral plane and cleavage direction. The diamond loss is exceptionally low; the direction of wear being toward the apex and highly resistant. However, the rate of penetration is retarded by the tendency to polish and the lack of a sharp point projection to aid rock penetration and breakage.

2—The positive rake is structurally weak. Furthermore, the wear across the octahedral face is in the softest direction. These two factors cause early stone failure and high diamond loss. The orientation cannot be recommended under usual conditions.

3—On point setting with octahedral face leading is a fair orientation. The movement is along the hardest direction of the cube face; i.e. diagonal. Tendency to polish is less than on the octahedral face. However, the point wears down rapidly to present a flat square surface, difficult of penetration. The bit must be broken in more carefully than when using a negative rake because the orientation is not so strong structurally.

4—A high negative rake of 30° is a compromise orientation sacrificing some diamond wear for increased rate of penetration. The setting is very strong structurally, and the trailing edge fractures just enough to give a rough cutting surface. If desired, more diamonds can be set in a given area than using the on point position. Some consideration might be given to supporting the trailing point by backing it with matrix. However, this backing might again increase the tendency to polish by resisting diamond fracture and by exposing a greater contact surface.

5—On point orientation, in a direction paralleling a crystallographic axis, apparently has the same merits and faults of setting 3. Performance is almost identical. If anything, diamond wear should be higher although fracture characteristics offset this somewhat.

Of course further test work is required to confirm the above results. This should be done now by operational testing in the field, as well as in the laboratory. It is recommended that the bit manufacturers consider orienting those octahedron crystals having discernible faces with a 30° negative rake. Meanwhile, it is hoped that research may be initiated to determine an easy production line technique of orienting diamonds crystallographically.

Future Research

Plans for further research on diamond orientation embrace the following aspects:

1—Testing three additional bits with the 30° negative rake settings, of which one or more bits will have the diamond points backed with matrix for support, as indicated in Fig. 8d.

2—Testing several bits set with cube diamonds. The first orientation of the cubes is as shown in Fig. 8f, approximating a 30° negative rake off the octahedral face.

3—Test procedures will be changed later, whereby drilling will be started, after break-in period, at a predetermined constant rate of penetration. This rate will be held as long as possible within the thrust limitations of the drill, and then allowed to taper down to a set minimum. This technique approximates more closely field practice with a feed screw unit.

4—Research on developing a simple method of obtaining crystallographic directions for diamonds lacking discernible faces.

5—Testing of West African diamonds of size 10 per carat with similar orientations to those used with Congo diamonds to obtain comparative performance data.

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Underground Mining Trends In The Great Swedish Export Iron Ore Mines

Fig. 1—The Kiruna ore mountain. The cleft shows the dip of the orebody.

by Borje Hjortzberg-Nordlund

THE great Swedish export iron ore mines are Kiruna and Malmberget in the north above the Arctic circle and Grängesberg in Central Sweden, see Figs. 1 to 3. These mines exported in 1951 about 13 million metric tons of high grade iron ore and concentrates.

The origin of these three ore fields seems to be the same. They are of pre-Cambrian age and are regarded as typical instances of primary eruptive ore that has thrust up as glowing masses of lava flow between two somewhat older beds of porphyry. Apparently the ore and the porphyry became segregated from common parent magmas by a process of differentiation.

Despite the fact that the Kiruna orebody belongs to the earli ·t pre-Cambrian formation, it has been influenced to an unusually small extent by later metamorphosisms, apart from its having been set on edge through folding and wrenching off by a number of later faults. The Kiruna ore occurs along a stretch of more than 4 miles as a series of slabs or lenses sloping steeply toward the east and sandwiched between two beds of porphyry. The main orebody has a length of about 3 miles and an average width of 300 ft with a maximum of 600 ft. The dip varies from 65° to 45° toward the east and the known depth is 3000 ft, although magnetic surveys indicate it may be at least 6000 ft.

Malmberget has undergone a more thorough transformation, having been pressed and crumpled into a meandering band of disconnected layers and lenses. The largest of the more connected bodies of ore, the Great Ore Layer, outcrops on a low mountain ridge and has a total length of about 4 miles and a maximum width of about 300 ft. The dip varies from 30° to 70° towards the north.

The main orebody in Grängesberg, the so-called

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Fig. 2—Formerly four dry-magnetic sorting plants of this type served each adit of the Malmberget mines. Today a centralized plant is being built to handle all the ore.

Export-Field, consists of a great lenticular slab tilted towards the east at 65° to 70°. It is about 300 ft wide and 1 mile long. A number of smaller orebodies occur in the footwall, and all of them are typical apatite ores; consequently they carry a high phosphorus content. Here as well as at Kiruna and Malmberget the ores are sharply defined against the surrounding rock and the intermixture of gangue is small.

The Grängesberg mine is owned by the Trafik AB (Traffic Co.) Grängesberg-Oxelösund (TGO), and Kiruna and Malmberget by a subsidiary company, Luossavaara-Kiirunavaara AB, (LKAB). In the latter company the Swedish Government as ground owner holds half the shares but has only a minority influence on the managing of the mines.

The three mines offer different problems. The trends will be analyzed but details discussed only when necessary.

Mining Methods

Hitherto Kiruna has been mined by the conventional open-pit method. Within the next few years, however, the mining will have to go underground. Then two mining methods will be considered. When possible, shrinkage stoping will be adopted with the stopes placed across the orebody. The distance between the haulage levels will be about 150 ft. If the hanging wall is not reliable, the dip too flat, or various grades of ore occur within the same area, shrinkage stoping is out of the question, and a kind of highly mechanized sublevel caving will be used. Each level will be divided into blocks 600 ft long, and as the orebody averages a width of about 300 ft, the blocks will contain between 4 and 5 million tons of ore. Distances between sublevels will be about 20 ft. As many ore winzes as are needed for the different ore qualities will be driven. The sublevel crosscuts will be 12 x 16 ft. When driving crosscuts, drilling probably will be done by the help of air-leg equipment. Advance should be 15 ft a shift, which would give about 400 tons of ore. When mining proper is started, automatically operated drill rigs will be used, and the daily capacity in each stope will be about 2000 tons, working two shifts. Loading and transportation will be trackless on sublevels but with tracks and trolley locomotives on haulage levels.

In Malmberget the same mining methods are used, but here conditions are often favorable for long-hole blasting. Both horizontal drilling from raises and vertical drilling from drifts have been tried successfully, and also long holes in combination with shrinkage stoping.

The Grängesberg orebody is frequently traversed by younger granite and pegmatite dykes, which make the ore roofs of the shrinkage stopes unreliable. Therefore, sublevel caving methods are used most often, and the ore at the stopes is loaded by Eimco-type loaders. Long-hole drilling in combination with caving has been tried rather successfully.

Since about 1930, time studies, referred to in these mines as work studies, have been a guiding factor. Today all kinds of work are studied carefully to find better methods and more suitable equipment. The results have been very satisfactory and have led to new developments in a number of different phases of underground mining.

However, studies of a small part of a large job may lead to absurdities if the whole is not properly considered. Therefore, when the work studies have been started, they should not be stopped until all jobs in underground mining are covered.

Drilling

The first job tackled was drilling. In choosing among different types of drilling machinery, the choice often was founded on personal likes and dislikes, with no objective basis for selection available. By thorough work and time studies there was designed, in collaboration with Atlas-Diesel Co., the well-known air-leg or jack-leg in combination with a number of rather small drills, which made a lighter type of drilling fast and easy. A complicated, more or less automatic, drilling equipment was obtained, which could be applied when conditions justified heavy machinery, see Fig. 4. This drill is typified by the Bux drill used in Kiruna. In both cases time losses were brought down to a minimum.

During the first studies of drilling operations, the question of drill steel proved of greatest importance. At about the same time the alloy steel was introduced, and it soon replaced the plain carbon drill steel. But the miners had to carry too heavy burdens of drill steel, which required much time in the stopes as well as in the transportation. Several kinds of detachable bits were tried, but the drilling results did not correspond to the costs. Then tungsten carbide bits were tested. From the beginning good results were obtained, but the high costs made excellent results imperative. An almost immense footage per bit was needed, and the average minimum considered in Malmberget was 1000 ft in ore and 500 ft in rock, comparable to bare granite. After 5 to 6 years of experiments and research, the Sandvik coromant bit reached that average, and about 1945 that steel was adopted for all kinds of drilling, and today it is used exclusively. A number of other tungsten carbide bits have also given good results, for example, the Fagersta Seco bit.

An interesting development occurred in Grängesberg. The mining method, sublevel caving with rather narrow crosscuts, made it necessary, when changing the longest drill steel, to bend the steel to get the depth of hole that gave optimum blasting results. This cannot be done with alloy steel, and the use of carbide bits with common carbon steel is not favorable, as the expensive bit outlives the steel. Then it was decided to solder the bit to a hollow flat

spring steel rod of good quality, which could be bent when inserting, see Figs. 5 and 6. The durability of the steel is most satisfactory, and no decrease in the drilling speed is noticeable.

As mentioned before, blasthole drilling has been widely—and almost always successfully—applied to different mining methods. Diamond drilling as well as drilling with hammer drills and carbide bits has been tried. The latter seems to be much less expensive but is not yet quite reliable, as it proved difficult to force enough water through the jointed drill steel. This problem, however, is being studied, and there is hope that soon diamond drilling will be necessary only when longer holes than 75 to 90 ft are required and that carbide bits will be used for shorter holes.

Blasting

For a long time the underground blasting practice followed conventional lines. During World War II as well as afterwards there has been a shortage of glycerine, and to maintain the same rate of detonation with the least possible consumption of glycerine, a number of aluminum explosives with a considerably lower content of nitroglycerine were developed, some of which have proved satisfactory and are now in common use in the mines. No increase of dangerous gases has been noticed.

When charging long holes, 5-ft long cardboard cylinders filled with the explosive at the plant are used. The charging requires about one third of the time needed for charging with cartridges of ordinary size. It is interesting that these cylinders, which have a 1.18-in. ID, contain 0.67 lb of dynamite per ft, while a diamond drill hole of 1¼ in. charged by hand takes only about 0.56 lb per ft.

After the last war, short delay blasting has been studied intensely in Sweden. In open-pit mining valuable results have been achieved. Underground long-hole blasting with short delays apparently results in better fragmentation and also in stronger roofs or walls, but it has been difficult to bring these facts out clearly, as in different mines and parts of mines conditions vary so rapidly that approximate statistics must be relied on, and to get even these requires a rather long time.

An effort is being made to increase the depth of the round when tunneling by blasting the burn cut in two short-delay blasts. On an average the depth of a round is 8 ft. There would be a gain in drilling as well as loading capacity if this depth could be increased to say 15 ft. First, the bottom 7 ft are charged and short-delay detonators applied, then a space of about 8 in. is filled with sand or gravel, and finally the outer part of the hole is charged. The short-delay detonators are so placed that the inner parts of the holes are ignited some milliseconds later than the outsides, just enough to remove the burden before the inner parts explode.

Loading

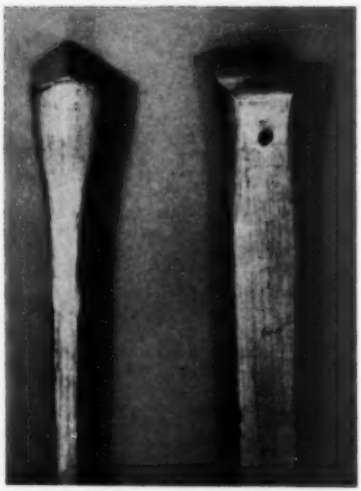
Formerly, loading and transportation normally represented about 40 pct of all underground shifts. Therefore, these operations were among the first to be penetrated carefully.

Hand mucking was one of the heaviest jobs in underground mining. When the time came that the young men did not want underground jobs and management had to try to make mining a more attractive profession, the first consideration was to eliminate hand mucking. A good mucker was able to load 25 tons of rock or 30 to 35 tons of ore a shift, but a man could stand this only 10 or 15 years. Thanks to American inventors and producers, operators now have a number of good loading machines, from scrapers and scraper hoists to shoveling machines of many different types and principles. Mucking is no longer a problem, but to maintain a flowing operation is difficult. Mechanized equipment is expensive and must be kept working as nearly continuously as possible, and here is a crucial point.

Fig. 3—Grangesberg—head frames, change houses, and dining hall.

In the narrow drifts of a mine, the rapid changing of cars has always caused debate. Cherry pickers, movable switches, passing tracks etc. are used, but are hardly ideal. When changing over to large cars, the problem is more difficult, even if a large car will keep the loader running a longer time for each car. It is believed that the best thing would be to have the loader working into a movable storage car with a discharging arrangement whereby the mine cars could go underneath and be filled quickly. This probably could be done easiest if the storage car is equipped with scraper chain conveyors for loading and unloading. The Joy loader type combined with shuttle cars solves the problem efficiently in places where trackless mining can be applied, which often is the case in Kiruna and probably also in Grängesberg and Malmberget. But in narrow development tunnels and drifts, where distances are long and no winzes are at hand, operators are still looking for the perfect design.

Generally speaking, however, loading from chutes is a better practice than scraping or machine loading. It seems more logical to let the ore run by gravity into the cars if possible. To avoid finger raises and grizzlies, there has been experimentation with large chute openings. When these are wider than 3 ft, they have been found hard to operate by hand, and consequently quite a large number of different types of air-operated chutes have been constructed. Some of these have 10x4-ft openings, see Fig. 7. When such a chute is running smoothly, a car of 20 to 25-ton capacity is loaded in 10 to 15 sec. Work studies of this type of chute have proved that one locomotive driver, one loader, and one man for secondary blasting may draw 1500 to 2000 tons a shift. Then, of course, conditions were not unfavorable, but there is doubt that this could be done by any



other kind of mechanical loading device in such a constricted space.

Through these chutes very large chunks of ore will be loaded in the cars. The question arose as to the proper size of these mine cars, from the haulage point of view, as large as possible. This meant that, in any case, they would be too heavy to be handled by manpower. If locomotives have to be used even at the loading points, the wheel load will be the size limiting factor. It was decided that 4 tons should not be exceeded, rail weights and tie costs also being considered. A four-wheeled car may then have a gross weight, load included, of 16 tons and a doubletruck car of 32 tons.

Long tests determined that doubletruck cars of 240-cu ft capacity should be used. As long as the older parts of the mines are worked, smaller cars, probably 100 to 130-cu ft Granby type four-wheeled cars must be used. Rotary dumping and also the use of Granby type cars is not favored, as in certain places the ore has a tendency to be sticky, and it is necessary to have men detailed to clean the cars. In Sweden today, the capitalized value of one man is at least 125,000 crowns or about $25,000, and obviously even for that reason it is important to avoid using more men than the absolute minimum. A bottom dumped mine car has been built, see Figs. 8 and 9. At one of the ends the bottom of the car is hinged to the body, and when the car is dumped it is placed on a hinged, counterbalanced dumping bridge. Then a catch is removed, and the bridge and the bottom dumps down to a sufficient angle while the body is resting on a steel frame. The car is emptied in a few seconds, and the counterweight brings the bridge up to horizontal position again. The speed is regulated by two double oil cataracts that perform this complicated task very efficiently. The bumpers of the cars are mounted on the body frame, and automatic couplings of Ohio Brass Co. manufacture will be used. The feeding of the cars on the bridge and the dumping will be mechanized and push bottom operated by the man in charge of the crushing station below the haulage level. A few of these cars have been running on trial in Malmberget, and costs of repairs have been suprisingly low.

For various reasons the intention is to crush the ore before hoisting. Too large lumps cannot be transported on conveyor belts. The filling of the skips and the hoisting should be automatic as far as possible. One of the engineers has designed a hydraulically balanced measuring pocket that will be filled and emptied automatically and seems to meet all requirements. But the ore must be of a size that will run easily. Generally, the purchasers want ore crushed below 4 in., and to facilitate this, as a rule, an underground plant will have to be designed to produce ore of that size, which, obviously, also conforms with plant requirements.

The primary crusher will be a single-toggle type with a receiving opening of 60x70 in. and discharge opening of 16 in. Secondary crushing will be facili-

Fig. 4—The Bux drills are rather heavy and are operated by one man and a helper.

Fig. 5—Carbide bits are soldered to a hollow, flat, spring-steel rod.

Fig. 6—Drill rods of hollow, flat, spring steel bend when inserted into the drillhole.

tated by either a Blake type or a gyratory crusher. Each crushing plant will be built for an average capacity of 1000 tons per hr.

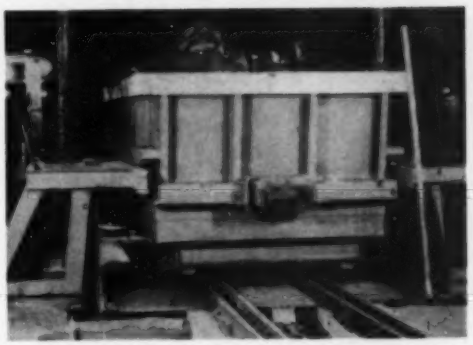
There are different methods for transporting the ore from underground to the surface. The Grängesberg mine is equipped with two drumhoists for ore hoisting and two Koepe-type hoists for men and materials—all more or less of conventional design.

The Kiruna central hoisting plant, now under construction, see Fig. 10, is planned for a maximum capacity of 4000 tons per hr. It consists of eight ore shafts and one man shaft. Each ore shaft is equipped with one Koepe-type hoist with a bottom dumping skip and counterweight, all designed by the Swedish firm ASEA. The skip weight is 15 tons and the useful load 20 tons. Four ropes of about 1.65 in. diam will be used. The diameter of the pulley is about 10 ft. Maximum hoisting speed will be 36 fps. Two shafts will serve one underground crushing plant. The hoists will be push-button operated but, naturally, there are provisions made for simple switching over to manual operation of each hoist. The speed control is effected by means of amplidyne generators according to a system similar to that employed by the General Electric Co.

There are several reasons for this arrangement. The rock is of such structure that rather narrow shafts will stand without any concrete linings while larger shafts have to be entirely concreted. The ore from the mine must be treated in a dry magnetic plant where one section will handle 250 tons. Two sections may be reached from one shaft without any mechanical transportation. The width of the sections gives a distance between shaft centers of about 45 ft. Ore will be hoisted from several levels alternatingly, and then either drum hoists or single-skip, Koepe-type hoists must be used. One rope for a load of 35 tons would be unwieldy, and the pulley or drum necessarily would be large. This is avoided by using several ropes, which is scarcely applicable to anything but the Koepe hoist.

In Malmberget it is intended to have conveyor belt transportation of the ore from the two or three first underground levels. The distance between levels is about 160 ft, which corresponds to 25 to 30 million tons of ore. The conveyor belt installation is of a rather new type, and a more detailed description follows.

For many years the Sandvik steel plant in Sweden has manufactured conveyor belts of cold-rolled, hardened and tempered steel. The material is of high grade charcoal quality, cold rolled to the following physical properties: tensile strength, 170,000 psi; proportional elastic limit, 136,000 psi; hardness (Vickers), 340 to 350; and endurance limit, 78,000 psi.



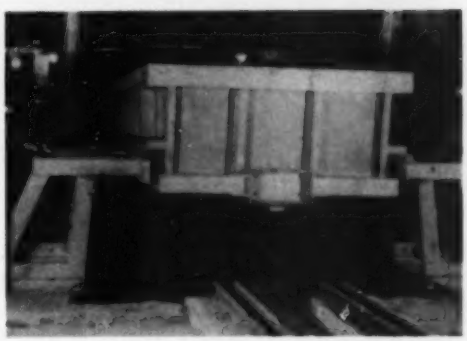


Fig. 7—An air-operated chute, 10x4 ft, permits a 20-ton or 25-ton capacity mine car to be loaded in 10 to 15 sec.

Fig. 8—The bottom of this double-truck car of 240 cu ft capacity is hinged to the body. When the car is dumped, it is placed on a hinged, counterbalanced dumping bridge.

Fig. 9—The body of the dump car rests on a steel frame while the two oil cataracts on each side of the car regulate the speed of the counterbalanced dumping bridge.

Fig. 10—Head frame and sorting plant as planned for Kiruna. The machinery for man hoists (left) and eight ore shafts (right) is placed in the machine hall 140 ft above ground level.

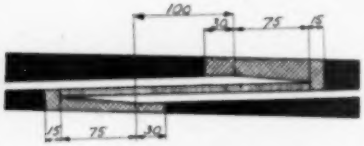


Fig. 11 (above)—Rubber covered steel conveyor belts are used in ore handling. A joint is shown here. The strength of the adhesive used in joining the rubber to the steel provides a bond greater in strength than the shear strength of rubber.

Fig. 12 (right)—When rubber on the belting wears away, there remains a thin layer of rubber that temporarily protects the steel until a patch is put on. In Malmberget, two belts of 700 tons per hr capacity will be required.

For years these belts in different widths and thicknesses have been used for conveying purposes when sticky and nonabrasive materials are being handled. For materials, such as iron ore, they have, however, their limitations. Therefore, to improve their surface to obtain better resistance against wearing, experiments have been conducted for a few years. The result is a rubber-covered steel conveyor belt. This implies that the steel belt is covered completely with rubber and fastened to the steel by a special method, see Fig. 11. The thickness of the rubber covers on the top and bottom of the belt is determined according to the same rules as have been adopted when specifying the cover plates on canvas rubber belts. The strength of adhesion between the steel and the rubber is even greater than the shearing strength of the rubber itself. If for some reason the rubber should be torn away from the steel, there would always remain a thin layer of rubber on the steel which, at least temporarily, protects the steel from corrosion until a new patch can be put on.

The belts are made endless by an overlapping joint. The two belt ends are glued together with a thin sheet of rubber between them and then vulcanized. By making a sufficiently large overlap, the joint can be made stronger than the belt itself, see Fig. 12. As a comparison it can be mentioned that with a shearing strength limit of 128,000 psi, an overlap of approximately 10 in. will withstand the same tension as a 1.66 mm thick, steel conveyor belt. The belt ends are tapered, and this is done to even the stresses in a joint when it passes over the terminal drums.

Fatigue tests indicate that belts and joints should stand combined tension and bending stresses up to 49,000 psi at 10 million bendings. From this it can be seen readily that rubber-coated steel belts possess favorable characteristics as regards the tensile strength, and this makes it possible to install long conveyors with high lifts.

In Malmberget two belts with a capacity of 700 tons per hr each will be needed. The total length is 1700 ft, the lift 490 ft, the belt width 27.5 in. and the thickness of the steel 1/16 in. A calculation shows that at a belt speed of 10 fps, there will be a total stress in the belt of 47,500 psi. Of these, 26,000 psi are required for the bending stresses when a 71 in. diam has been selected for the driving terminal drum, while the pull in the belt is 21,500 psi.

The mechanical accessories are principally of the same design as those used for canvas rubber belts. Some deviations are, however, to be noted, e.g., the total width of the idler sets is somewhat narrower than the width of the belt, and the idler rollers are fastened on springs, which makes the idler sets flexible and enables the idler rollers to adapt themselves to the natural troughing of the belt. If the right choice of springs has been made, the individual idler rollers will always be in contact with the belt, regardless of whether the belt is loaded or unloaded. This ensures a minimum of wear and keeps the transversal bending stresses in the belt due to the troughing within the allowed limits.

An effort has been made to give a short description of the trends in underground mining. Of necessity, this has been a brief account, and there are numerous other problems which have been penetrated to get the best possible total results. The Swedish Ironmasters Association (Jernkontoret) has organized the Mining Research Committee which has aided greatly the mining industry. Today a number of these research groups are studying different problems, among which are: magnetic surveying, rock bursts, explosives and blasting, tungsten-carbide bit drilling, air leakage, track resistances, etc. The research comprises fundamental scientific research and empirical field work. The results are either published or distributed only to the sponsors of the Research Committee.

However, in a few years today's trends should be actual practice. It is hoped that at that time mine production will increase, not only in the interests of Swedish companies, but because there is a serious world shortage of high class iron ore.

Adsorption on Quartz, From An Aqueous Solution, Of Barium and Laurate Ions

by A. M. Gaudin and C. S. Chang

Adsorption was measured for barium ion and laurate radical, using radioactively marked agents, over wide range of concentrations. Laurate adsorbed in absence of barium fails to float. With barium, flotation-effective laurate coating needs not exceed 5 pct of monolayer. Barium adsorption then is several fold larger. No barium laurate coating is obtained.

IN general, fatty acids or their alkali salts do not cause clean quartz to float. However, the presence of multivalent ions, such as the alkaline-earth metal ions and heavy-metal ions, can activate quartz and thus make it respond to soap flotation.

The mechanism of activation and soap flotation of quartz has been studied.[1-4] The problem was attacked by making flotation tests rather than by careful adsorption measurements on suspensions of ground quartz in solutions containing the activator and the collector. Attempts have been made to determine the adsorption of barium ion and calcium ion on quartz. The results have only qualitative value as the analytical methods were not adequately precise.

Artificial radioactivity and progress in radioactivity detection have introduced a new analytical tool, which can have a sensitivity several orders of magnitude greater than that of other methods.[5-6] In the experimental work described in this paper the radioactive tracers, barium 140 and carbon 14, were employed. Lauric acid was synthesized, having a radioactive carbon atom and was used with Ba^{140} to study the adsorption of barium and laurate ions from aqueous solution on ground quartz. Flotation tests, using the vacuum flotation technique,[4] were run in conjunction with the adsorption experiments. The object of this investigation was to understand better the reaction mechanism of barium activation and soap flotation of quartz.

Methods and Materials

Quartz Sample Preparation: Lumps of hand-picked quartz, washed free of stains, were reduced in size to −20 mesh in laboratory crushers. The product was boiled in concentrated hydrochloric acid to remove the abraded iron. The cleaned product then was ground dry in a laboratory porcelain mill, using siliceous pebbles, to pass through a 200 mesh screen.

The ground product was deslimed by sedimentation at 37 microns. This −200 mesh +400 mesh material was subjected again to boiling with concentrated hydrochloric acid, followed by washing with distilled water and further desliming. The cycle was repeated until no trace of iron could be detected in the wash liquor. During the final washing, the pH of the wash water was checked to insure the complete removal of the acid from the mineral. The quartz then was rinsed with conductivity water. The resulting product was dried in a drying oven and stored in mason jars.

The impurities (spectrographic) were as follows: Al, 0.01 to 0.001 pct; Li, Mg, Mn, Na, each less than 0.001 pct; Fe and Cu not detected.

The specific surface of the quartz sample was determined by the krypton gas adsorption method.[7] The average of two measurements was 881 sq cm per g. The calculated specific surface for 37/74-micron quartz particles, using a surface factor of 1.96,[8] is 900 sq cm per g. This is in good agreement with the measured value of 881 sq cm per g.

Beta-Counting Method: The radioactive isotope of barium used in the experimental work was barium 140. It has a sufficiently long half-life, 12.8 days, emits high-energy beta particles (up to 1.0

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Abstracted from the thesis for the Doctorate in Mineral Engineering by Chen-Siang Chang, May 1951.

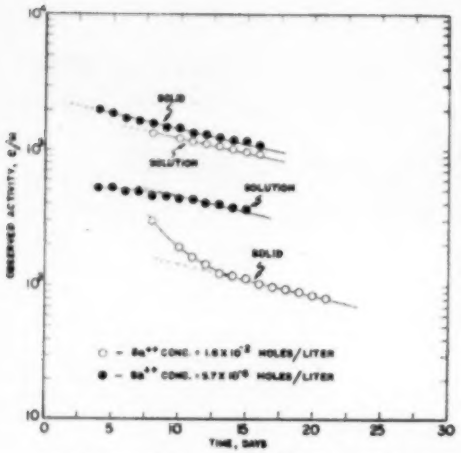

Fig. 1—Gross decay curves of Ba^{140}-La^{140} in samples.

Mev[5]) and is obtainable in high specific activity. The decay scheme is as follows:

$$Ba^{140} \xrightarrow[12.8d]{\beta.\gamma} La^{140} \xrightarrow[40h]{\beta.\gamma} Ce^{140}$$

The fact that Ba^{140} decays to a radioactive daughter La^{140} of 40-hr half-life complicates the counting procedure. But the presence of La^{140} which emits hard beta (70 pct 1.4 Mev, 20 pct 0.90 Mev and 10 pct 2.12 Mev)[5] increases the ease of detection.

Chemically the coexistence of La^{140} when using Ba^{140} as a tracer for barium in an adsorption test will not affect materially the result. Calculation shows that even in the most adverse case there are not less than 25 million times as many stable barium atoms as of radioactive La^{140} atoms. The *chemical* effect of the lanthanum therefore can be neglected.

In radioactive measurements, however, the effect of these La^{140} atoms cannot be ignored. The partition of La^{140} in an adsorption test between quartz and solution may not be the same as that of Ba^{140}. For this reason, attainment of radioactive equilibrium (between La^{140} initially present, La^{140} growing from Ba^{140} and Ba^{140} present) after the mineral-solution separation becomes a necessary prerequisite for all activity measurements. An aging period must be allowed between the time an adsorption test is completed and the subsequent radioanalyses of the test products.

The decay curves of the solid and solution samples from two barium adsorption tests at barium concentrations of 0.0057 and 16 millimol per liter are shown in Fig. 1. At the low concentration the tracers on the mineral reach equilibrium ahead of those in the liquor (11 days). The reverse was true in the case of the test at high concentration. In that test it took 14 days for radioactive equilibrium on the mineral. Therefore, the aging period necessary varies. Inasmuch as all the tests were conducted within the range of concentration shown in Fig. 1, an aging period of 14 days was adopted for all the samples. Radiochemical calculation indicates that aging for 2 weeks would give complete equilibration for samples initially overrich in barium 140, and for any samples overrich in lanthanum 140, provided the lanthanum excess is not more than tenfold. If a

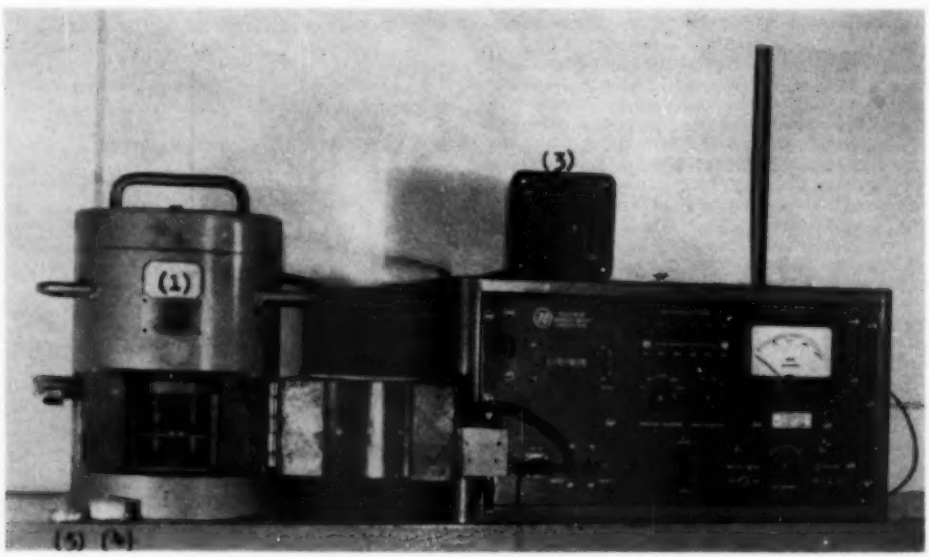

Fig. 2—Counting equipment for radiobarium.

1—Lead housing with end-window inside
2—Model L-143 scaler
3—Tl timer
4—Lucite counting container for solid sample
5—Aluminum counting cup for solution sample

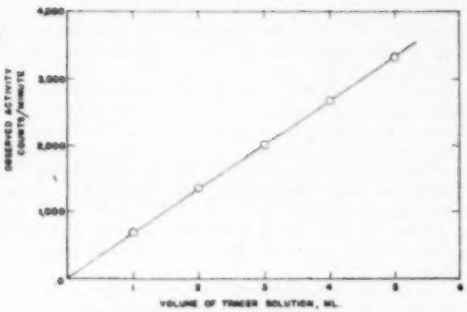

Fig. 3—Proportionality of amount tracer and observed activity in solution counting.

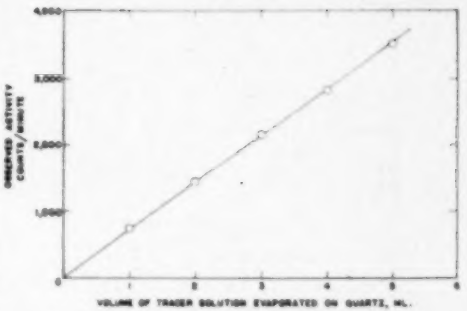

Fig. 4—Proportionality of amount tracer and observed activity in solid counting.

more extreme excess of lanthanum is to occur, still longer than 14 days should be allowed. Incidentally, Fig. 1 suggests that lanthanum is adsorbed on quartz, under the experimental conditions tested, to a greater extent than barium.

The instrument used for radiobarium measurement is shown in Fig. 2. It consists of a mica end-window counter housed in a lead chamber provided with a carefully machined lucite holder with five different geometry shelves, a Model L-163 scaler and a Tl timer manufactured by the Nuclear Instrument & Chemical Corp. of Chicago.

For measurement of radiobarium in solution, the sample was prepared by evaporating a certain volume of the solution in an aluminum counting cup. The linear relationship of the counting rate to amount of tracer is shown in Fig. 3.

To have the same geometry for counting solid samples, in this case, quartz with adsorbed barium, it was necessary that a constant weight of sample be used for each measurement. In all the adsorption experiments 15 g of quartz were used. Therefore, all solid countings were made with 15-g samples. This is more than twice the quantity of quartz needed to provide infinite thickness[10] for the (2.12 Mev.) maximum energy beta-ray of Ba^{140}.

The proportionality between the observed activity and the amount of barium coating on quartz was checked by determining the counting rates of five 15-g samples of quartz on which different quantities of tracer solution had been evaporated, as illustrated in Fig. 4.

To correlate the data from solid and solution countings, the ratio of observed counting rates per unit quantity of tracer in the two methods of counting was determined.

When running a series of barium adsorption tests, the initial tracer concentration was kept constant by adding the same quantity of tracer in each test. For comparison, a standard was prepared by evaporating a certain volume of solution having the same initial tracer concentration as that in each of the adsorption tests. The adsorbed barium and barium in solution were obtained by comparison of the observed activities of the samples from the adsorption experiment to that of the standard.

Radioanalysis Technique: The radioanalysis of labeled lauric acid required conversion of the organic compound into carbon dioxide. This was accomplished by boiling it in the van Slyke-Folch combustion mixture.[11] The carbon dioxide formed was separated from the other gaseous products of combustion by fractional distillation. The activity of the gas was measured by the internal gas counting method originally developed by Miller and Brown.[12, 13] Details have been given previously.[6, 14]

All samples, quartz and solution, from adsorption tests in which lauric acid was used were dried slowly at room temperature by natural evaporation. After evaporation, the samples were placed in the combustion chamber of a wet combustion train for further processing.

Double Tracing Procedure: The fact that C^{14} has a weak maximum beta emission energy (0.154 Mev)*

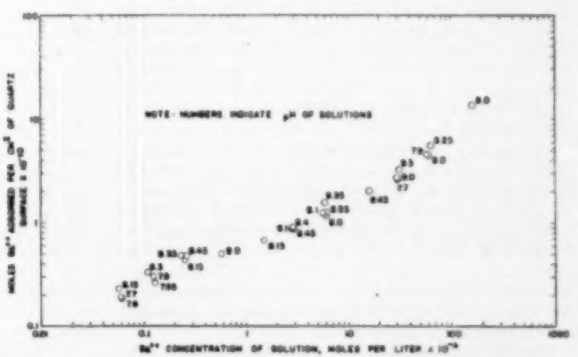

Fig. 5—Adsorption of barium on quartz, effect of barium-ion concentration.

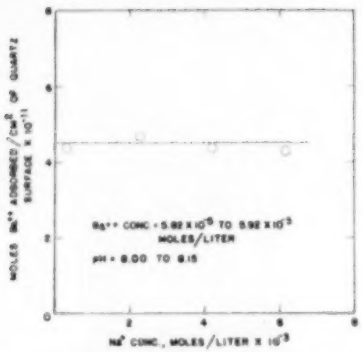
MOLES Ba++ ADSORBED/CM² OF QUARTZ SURFACE X 10¹¹
Ba++ CONC. = 5.82 X 10⁻⁵ TO 5.92 X 10⁻³ MOLES/LITER
pH = 8.00 TO 8.15
Na+ CONC., MOLES/LITER X 10⁻³

Fig. 6—Adsorption of barium on quartz, effect of Na^+.

and that barium does not form a gaseous compound when subjected to a wet combustion process played an important role in making possible the use of the two tracers in one experiment.

The activity of C^{14} can be shielded completely by the use of an absorber having a thickness of approximately 30 mg per sq cm.[10] In these tests, the radiobarium, in spite of the presence of C^{14}, was measured in the usual manner except that an aluminum absorber, 35.8 mg per sq cm, was placed between the mica end-window counter and the sample. There was no change in the method of analysis for the C^{14} marked lauric acid.

For a sample of quartz coated with both barium and laurate, the radiomeasurement of barium preceded that of the C^{14}.

Adsorption Test Procedure: A weighed 15-g sample of clean ground quartz was agitated in a stoppered 100-ml glass cylinder for 1 hr in an agitation machine with 60 ml of solution containing reagents such as tracer barium, barium nitrate, marked and unmarked lauric acid, sodium hydroxide, sodium nitrate, and hydrochloric acid, depending on the nature of the test. The mineral and the solution then were separated by filtering through a Buechner fritted disk funnel.

To insure the attainment of equilibrium conditions, the filtrate was percolated slowly through the mineral bed five times. The mineral bed was kept covered with solution at all times. At the end of the filtration the fritted disk funnel containing the solution-covered mineral bed was placed in a lusteroid centrifuge tube provided with a rubber cushion and stopper. Further removal of solution from the quartz was accomplished by centrifuging at approximately 2700 rpm for 3 min. The final moisture content ranged from 1.5 pct to 4.5 pct depending on the conditions of the test.

The quartz cake was transferred to a beaker by gentle tapping and applying a slight air pressure to the stem of the fritted disk funnel. The beaker then was given a glass cover and weighed. The cake later was allowed to dry in the beaker and reweighed to determine its moisture content. In the radioanalysis of adsorbed reagents, a correction was provided for the retention of moisture by the quartz. Another small correction was made for handling losses incurred in the quantity of mineral.

The pH of the filtrate was measured with a Beckman Model G pH meter. For the radiobarium in solution, a sample was prepared by evaporating 5 ml of the filtrate in an aluminum counting cup of approximately 3.3-cm diam and 0.7 cm high. For laurate in solution, 1 to 10 ml of the filtrate, depending on the amount of C^{14} activity added, was evaporated in a 10-ml glass beaker, and this beaker was introduced bodily in the wet-combustion flask.

The mode of evaporation of the moisture in the samples, solid and liquid, was governed by the presence or absence of lauric acid in the test. When laurate ion was to be measured, the samples were dried only by exposure to the air at room temperature.

In addition, duplicate standard samples were prepared by evaporating in an aluminum counting cup 5 ml of solution having the same initial barium tracer concentration.

All adsorption tests were run at room temperature, 25 ±3°C.

Vacuum Flotation Test:[4] A sample of approximately 0.5-g clean ground quartz was conditioned with 60 ml of solution in a stoppered 100-ml glass cylinder for ½ hr by agitation. The glass stopper then was removed, and a vacuum line was connected to the glass cylinder. The floatability of the quartz under the existing condition then was observed.

Reagents: For the preparation of solutions, conductivity water only was used. Tracer barium: barium 140 in equilibrium with lanthanum 140, obtained by purification of fission products, was purchased from the National Laboratory at Oak Ridge, Tenn. The tracer came in the form of acidified $Ba(NO_3)_2$ or BaCl, solutions.

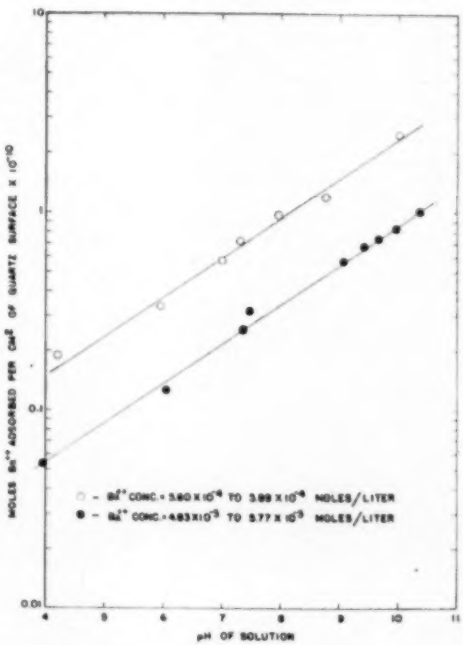
MOLES Ba++ ADSORBED PER CM² OF QUARTZ SURFACE X 10⁻¹⁰
○ – Ba++ CONC. = 5.80 X 10⁻⁴ TO 3.88 X 10⁻³ MOLES/LITER
● – Ba++ CONC. = 4.83 X 10⁻³ TO 5.77 X 10⁻³ MOLES/LITER
pH OF SOLUTION

Fig. 7—Adsorption of barium on quartz, effect of pH.

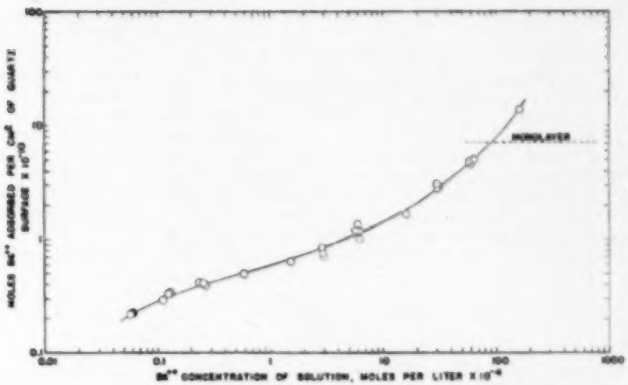

Fig. 8 — Adsorption of barium on quartz, effect of barium-ion concentration at pH 8.

Lauric acid: Harwood and Ralston[10] of Armour and Co. synthesized the radiomarked 12-carbon normal alkyl acid used in these experiments. Part of the carbon in the carboxyl group was replaced with carbon 14. The strength of the radioactive lauric acid was approximately 0.03 millicurie per g. Harwood and Ralston also prepared unmarked lauric acid of high purity.

Because of its low solubility in water, the lauric acid was dissolved by digestion in sodium hydroxide solution. It was in this form that the laurate radical was introduced in the adsorption tests.

Sodium hydroxide solution: Purified sodium hydroxide solution was made as follows: A concentrated aqueous solution (approximately 1 : 1) was prepared, centrifuged to remove the carbonate and other insoluble materials,[4] and diluted to approximately 0.3 N strength. This was then standardized against a standard solution of hydrochloric acid. Solutions of 0.05, 0.01 and 0.0031 N strength were prepared by further dilution of the purified and standardized sodium hydroxide solution.

Other chemicals: Other chemicals such as unmarked barium nitrate, sodium nitrate, and hydrochloric acid, used in the experiment, were of analytical reagent grade.

Experimental

Adsorption of Barium on Quartz: Effects of Ba^{++} concentration: The quantity of barium ion adsorbed on quartz was measured over a 5000-fold range in barium-ion concentration (from 0.0057 to 16 millimol per liter). The pH, in spite of the attempt to maintain it at about 8, varied from 7.55 to 8.45. The reagent used to regulate the pH was sodium hydroxide. Sodium ion, equivalent to 0.26 millimol per liter, was present in each test.

The data, which are shown in Fig. 5, confirm the finding of Gaudin and Rizo-Patrón[5] that quartz adsorbs barium ion. The amount adsorbed, however, depends on the barium concentration of the solution.

Effect of Na^{+}: To evaluate the effect of sodium ion on barium adsorption, the concentration of sodium ion was varied from 0.28 to 6.2 millimol per liter. Aside from the sodium ion provided by sodium hydroxide, the remainder was introduced in the form of sodium nitrate. Both barium ion and pH of the solution were kept constant with the former at approximately 0.059 millimol per liter and the latter at 8.15.

It can be seen in Fig. 6, a graphical representation of the data, that sodium at concentrations up to 6.2 millimol per liter does not affect materially the adsorption of barium by quartz.

Effect of pH: Two series of tests were run to evaluate the effect of pH. The barium concentration was maintained at approximately 0.052 and at 0.57 millimol per liter, respectively. The pH was varied from 4 to 10. Dilute hydrochloric acid was added to make the circuit acid whereas sodium hydroxide provided alkalinity.

Fig. 7 shows that the amount of barium adsorbed increases as the solution becomes increasingly alkaline. The change is not sharp since there is only approximately a 58 pct increase in adsorbed barium for every tenfold increase of hydroxyl-ion concentration.

On the basis of the variation of barium adsorption with pH, it is possible to adjust the barium adsorption data of Fig. 5 to a uniform pH, say 8.0, by the use of the effect shown in Fig. 7. The results are presented in Fig. 8. Only a portion of the data, at barium concentrations ranging from 0.015 to 0.3 millimol per liter, follows the Freundlich adsorption equation, $y = kC^n$. In this equation, y is the amount adsorbed, C the concentration of the adsorbate, and k and n are empirical constants. The slope of the line, n, in this case is approximately equal to 0.3. Beyond 0.3 millimol per liter, the slope increases with increasing barium concentration. It is interesting to note that the barium adsorption of quartz can extend beyond the monolayer. A surface concentration of 7.1×10^{-10} mol per sq cm is considered to represent a monolayer calculated on the assumption that the area for each adsorption site of quartz is equal to 23.4 A².[11]

Adsorption of Laurate on Quartz: Effect of laurate-ion concentration: The amount of laurate adsorbed at laurate concentrations ranging from 0.02 to 6 millimol per liter was determined. The pH of the solution was held at about 10. Since sodium hydroxide was used to digest the fatty acid, and also to maintain the high alkalinity, the sodium-ion concentration was not constant (1 to 7 millimol per liter).

The results, plotted in Fig. 9, show that quartz adsorbs laurate from solution containing sodium-hydroxide-digested lauric acid. The quantity adsorbed depends on the laurate-ion concentration and

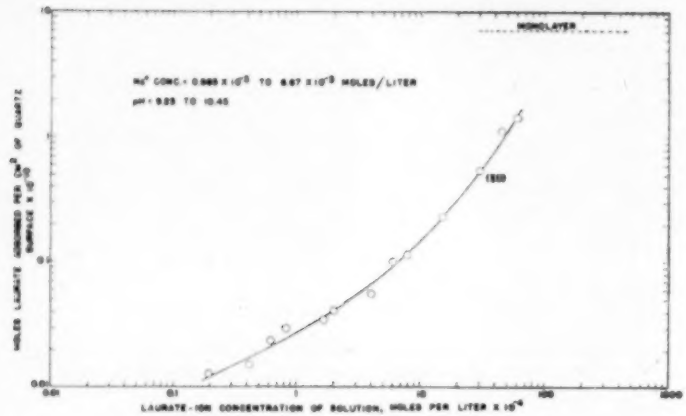

Fig. 9 — Adsorption of laurate on quartz, effect of laurate-ion concentration.

is approximately one order of magnitude lower than the amount of barium adsorbed at the same concentration.

In batch vacuum flotation tests, no evidence of flotation was observed under the conditions shown in Fig. 9.

Effect of Na^+ and pH: All the tests, numbering 12, in this series were run at constant laurate concentration, namely, 0.17 millimol per liter. In four of the tests the pH of the solution was maintained at about 9.6 while the sodium concentration was varied from 0.83 to 6.7 millimol per liter. Sodium nitrate supplied the sodium ion in excess of the 0.83 millimol per liter provided by sodium hydroxide. In the remainder of the tests only sodium hydroxide was used to vary both the pH from 8.8 to 11.4 and sodium-ion concentration from 0.5 to 5.5 millimol per liter.

The results, shown in Fig. 10, indicate that increase of sodium-ion concentration increases laurate adsorption by the quartz. Varying pH from 8.8 to 11.4 does not seem to have any effect at all.

Coadsorption of Barium and Laurate on Quartz: Since under the test procedure adopted for the adsorption studies it was impossible to separate the ground mineral from whatever chemical precipitate might be formed, it was necessary to conduct all the tests at conditions under which barium laurate would not precipitate. For this reason the solubility product constant of barium laurate was determined.

The Tyndall-cone method[16,17] was chosen since it did not require an elaborate experimental setup and yielded reproducible results. The average of two experimental determinations gave 4.3×10^{-13} as the solubility product constant of barium laurate at 25°C. Therefore, the concentrations of barium and laurate in the tests were fixed in such a way that the product of barium concentration multiplied by the square of laurate concentration was less than 4.3×10^{-13}.

Effect of Barium on Laurate Adsorption: A series of six tests was run in this experiment. The laurate and sodium concentrations were controlled at approximately 0.17 and 1.7 millimol per liter, respectively. The pH of the solution was held close to 10.15. The barium concentration was varied from 0 to 0.12 millimol per liter.

The data, plotted in Fig. 11, show a definite increase of laurate adsorption with increase of barium activation.

Examination of Figs. 10 and 11 show that laurate adsorption is greater in the presence of activating barium ion than in the presence of nonactivating sodium ion. Increase in barium concentration also causes a much more rapid increase of laurate adsorption than does increase of sodium concentration. Even at the highest Ba^{++} concentration tested the adsorption of laurate falls short by a factor of ten from being stoichiometrically in accord with formation of BaL_2. (*L* indicating the laurate ion).

No flotation of quartz was observed in tests run under the conditions of Fig. 11.

Laurate Effect on Barium Activation: This experiment included three series of tests.

1—The first series consisted of eight tests. The barium concentration of the solution was maintained at about 0.017 millimol per liter and the pH at approximately 10. The laurate concentration was varied from 0.075 to 0.6 millimol per liter. No attempt was made to control the sodium-ion concentration, which ranged from 1.6 to 2.5 millimol per liter.

2—In the second series, consisting of ten tests, the barium concentration was held at about 0.057 millimol per liter and the pH in the neighborhood of 10. The laurate concentration was varied from 0.04 to 0.27 millimol per liter. The sodium concentrations ranged from 1 to 2 millimol per liter.

In one instance, to test the reversibility of the adsorption reaction, the sequence of reagent addition in three duplicate tests, points A in Fig. 12, was varied. The activator and the collector were added simultaneously in the first experiment. In the second, the activator was added first, followed by the collector. This sequence was reversed for the last test.

3—The barium concentration in the third series (six tests) was kept essentially the same as that of the second series, namely, near 0.057 millimol per liter. The pH, however, was increased to approximately 11.1 instead of 10. The laurate concentration in the tests covered a range from 0.042 to 0.25 millimol per liter. The sodium concentration ranged from 4.3 to 5.2 millimol per liter.

The data of the three series of tests are shown in Fig. 12. Included in Fig. 12 is a portion of the data

of laurate adsorption on unactivated quartz previously shown in Fig. 9.

Vacuum flotation tests of the quartz indicated that flotation took place only under the conditions of Tests No. 91 and 92, see Fig. 12. From the results shown in Fig. 12, it appears that:

1—The adsorption of activator, barium, is independent of the concentration of the collector, laurate, see upper part of Fig. 12.

2—The adsorption of barium and laurate on quartz is independent of the sequence of reagent addition, points A.

3—The adsorption of laurate increases considerably with increase in barium concentration, that is, increase in barium adsorption. In other words, adsorption of collector is dependent on the degree of activation, see lower part of Fig. 12.

4—Laurate adsorption on barium-activated quartz increases more rapidly with increase of laurate concentration than does laurate adsorption on unactivated quartz, see lower part of Fig. 12.

5—The quantity of adsorbed barium on a mol basis is always greater than that of adsorbed laurate and usually much greater even at a collector concentration 30 times greater than that of activator, see B.

6—Laurate flotation of barium-activated quartz is possible at reagent concentrations well under those required to precipitate barium laurate.

7—The conditions for quartz flotation, as indicated by the results of Test No. 91, are surface concentrations of 1.85×10^{-10} mol of barium per sq cm and 3.23×10^{-11} mol of laurate per sq cm.

In terms of surface coverage, those conditions for flotation represent roughly 26 pct of a complete activator coating and 4.5 pct of a complete collector coating.

Discussion of Results

The experiments described in this paper accord with the adsorption theory of flotation,[15, 17] but they do not substantiate the theory of Taggart, Taylor, and Knoll.[16] For that theory to hold, barium laurate must be precipitated on the quartz surface. And, if that were the case, the following would also be true:

1—The amount of barium at the mineral surface would be dependent on the concentration in solution of laurate.

2—Two laurate ions for each barium ion would report on the mineral surface.

3—Flotation would take place only at concentrations of barium and laurate such that the solubility product constant of barium laurate is exceeded.

The experimental findings do not satisfy the above requirements.

Schuhmann and Prakash[4] proposed the following equation to represent the barium activation reaction at the locus of a ruptured bond on the quartz surface,

$$\boxed{SiO_2}^{-H} + Ba^{++} + 2OH^- \rightleftharpoons \boxed{SiO_2}^{-Ba\text{-}OH} + H_2O \qquad [1]$$

If N_{BaOH} and N_H are the surface concentrations, in mol of adsorbate per unit area, of $(BaOH)^+$ and H^+ respectively, application of the Langmuirian concept of adsorption and the law of mass action give the expression

$$K_1 = \frac{(N_{BaOH})}{(N_H)\,(Ba^{++})\,(OH^-)_2} \qquad [2]$$

In this equation (Ba^{++}) and (OH^-) are the concentrations of barium and hydroxyl in the solution and do not represent conditions of saturation of barium hydroxide.

Assuming that all the adsorption sites are occupied by either $(BaOH)^+$ or H^+, N_H is therefore equal to $(N_s - N_{BaOH})$ where N_s is the surface concentration of adsorbate at surface saturation. A surface concentration of $N_s = 7.1 \times 10^{-10}$ mol of adsorbate per sq cm of quartz would make up a complete monolayer. If N_s is large compared to N_{BaOH}, N_H is essentially constant. Even at 25 pct coating with Ba as $(BaOH^+)$ no large error is caused by assuming N_H constant. By keeping the barium-ion concentration constant, eq 2 can be simplified further to give the following approximation:

$$\log (N_{BaOH}) = \log K + 2(pH) \qquad [3]$$

A plot of log (N_{BaOH}) vs. pH would give a straight line with a slope of two. This, however, does not seem to be the case as can be seen in Fig. 12. The slope is approximately 1/5 instead of 2. It certainly would be more enlightening if the surface concentrations of ions other than barium were known.

The fact that the adsorption of barium is independent of the presence of laurate suggests that the reagents are not adsorbed from solution as $(BaL)^+$ but as individual barium and laurate ions. Since barium adsorption is greater than laurate adsorption, it is also justifiable to assume that each adsorbed barium can hold not more than one laurate. This is in accordance with the views held by Gaudin and Rizo-Patrón.[3] From the study of the mechanism of barium activation and oleate flotation of quartz, they postulated the sequential adsorption of barium and oleate, and that only one oleate can attach to one adsorbed barium.

It is interesting to speculate on the exact position of the adsorbed cation and anion. The filtration-followed-by-centrifuging procedure that was used to separate the loaded mineral from the liquor did not part the solid from the solution at the solid boundary but within the liquor. Actually the film of liquid surrounding the quartz is estimated to have been about 1700 A thick, in those cases where the least liquid was retained in the pores of the centrifuged cake. This suggests that at least a part

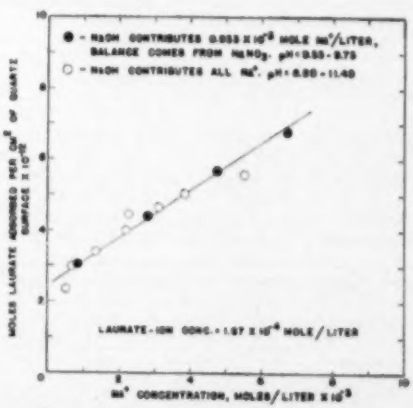
● - NaOH CONTRIBUTES 0.053 X 10⁻³ MOLE Na⁺/LITER, BALANCE COMES FROM HNO₃, pH = 0.50 - 9.75
○ - NaOH CONTRIBUTES ALL Na⁺, pH = 9.80 - 11.40
LAURATE-ION CONC. = 1.97 X 10⁻⁴ MOLE/LITER
MOLES LAURATE ADSORBED PER CM² OF QUARTZ SURFACE X 10¹⁰
Na⁺ CONCENTRATION, MOLES/LITER X 10³

Fig. 10—Adsorption of laurate on quartz, effects of Na^+ and pH.

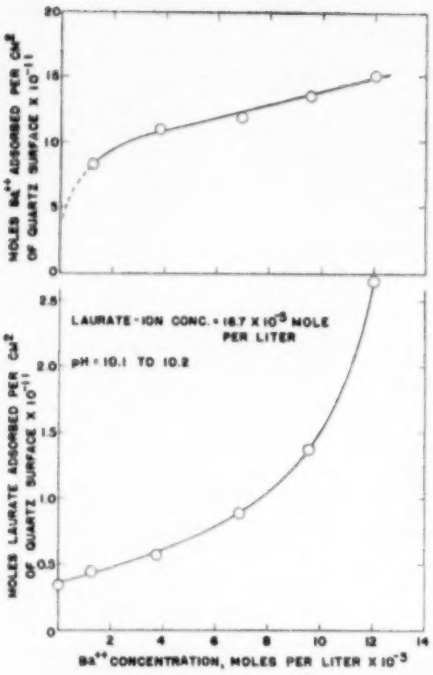
MOLES Ba^{++} ADSORBED PER CM^2 OF QUARTZ SURFACE X 10^{-11}
LAURATE-ION CONC. = 18.7 X 10^{-5} MOLE PER LITER
pH = 10.1 TO 10.2
MOLES LAURATE ADSORBED PER CM^2 OF QUARTZ SURFACE X 10^{-11}
Ba^{++} CONCENTRATION, MOLES PER LITER X 10^{-3}

Fig. 11—Coadsorption, effect of barium on laurate adsorption.

and probably most of the so-called diffused double layer known to colloid chemists has been included in the centrifuged cake along with the anchored part of the double layer. It must be noted that it is impossible to part the mineral from the solution within the diffuse layer without causing a rearrangement of the adsorbed ions. Further, it is inevitable that the mineral-solution separation be effected so as to include the diffused double layer present on the particles at the time the separation is made.

The thickness of the diffused double layer, δ in centimeters, has been identified as the reciprocal of the Debye-Hückel function, κ.[31]

$$\delta = \frac{1}{\kappa} = \sqrt{\frac{1000\,DRT}{8\pi e^2 N^2}} \cdot \sqrt{\frac{1}{c}} \qquad [4]$$

In this equation, D is the dielectric constant (about 80 for water at 25°C), R is the gas constant, 8.314×10^7, T is the absolute temperature (298 at 25°C), e is the charge of the electron, 4.77×10^{-10} electrostatic units, N is the Avogadro number, 6.02×10^{23}, and c is the ionic concentration of the solution in gram-ions per liter or moles per liter.

Thus for water at 25°C,

$$\delta = 3.05 \times 10^{-4} \sqrt{\frac{1}{c}}\ \text{cm} \qquad [5]$$

The lowest concentration of either barium or laurate in experiments described in this paper is 5.7×10^{-4} mol per liter, see Fig. 5. The thickness of the diffused double layer at this ionic concentration is roughly 1300A. The quartz sample in the adsorption tests retained a minimum of 1.5 pct moisture at the end of mineral-solution separation. Since the quartz sample has a specific surface of 881 sq cm/g, each quartz particle has, therefore, a liquid layer approximately 1700A thick all around it. This extends to include the diffused double layer. In spite of the fact that a correction has been provided for the reagents in the retained moisture, the measurements of adsorbed reagents prescribed by the methods described in this paper represent not only those adsorbed on the mineral surface, inner layer, but also those adsorbed within the diffuse layer. This is in agreement with the fact that quartz can adsorb barium in a quantity more than that necessary to form a monolayer, see Fig. 8.

With the incorporation of the concept of diffused double layer, it is interesting to compare the results of Tests No. 50 (see Fig. 9) 86, 91, and 92 (see Fig. 12). The surface conditions of the quartz and its floatability are given in Table I.

Although laurate adsorption is roughly the same in each test, flotation of quartz was not obtained unless a certain minimum barium adsorption was effected. The degree of barium activation seems to be the determining factor. This substantiates the view that as long as there is sufficient concentration of collector present, quartz flotation is activator-controlled rather than collector-controlled.

Based on the foregoing evidence, the following hypotheses are proposed:

1—Only the reagents adsorbed in the inner layer are responsible for flotation.

2—In the absence of an activator in a flotation system necessitating the use of an activator as well as collector, very few collector ions are adsorbed on the mineral surface. But there may be a considerable concentration of collector ion in the diffuse layer, a short distance away.

3—The presence of an activator tends to encourage the migration of the collector ions onto the mineral surface.

Table I. Surface Conditions of the Quartz and Its Floatability

Test No.	Barium Adsorption Mol/cm²	Barium Adsorption Coverage, Pct	Laurate Adsorption Mol/cm²	Laurate Adsorption Coverage, Pct	Vacuum Flotation Test
50	0	0	5.22×10^{-11}	7.4	negative
86	1.38×10^{-10}	19.6	4.18×10^{-11}	5.9	negative
91	1.85×10^{-10}	26.0	3.21×10^{-11}	4.5	positive
92	1.88×10^{-10}	26.5	4.25×10^{-11}	6.0	positive

Summary and Conclusions

Radioactive barium and radioactive-carbon-labeled lauric acid were used to study the adsorption of barium and laurate at equilibrium on a sample of ground quartz. In this paper *adsorption* is used to mean the amount measured to have been abstracted without reference to the position the abstracted material holds in the double layer surrounding the adsorbent.

From the results of the experimental work the following conclusions are reached:

Regarding barium adsorption: 1—Quartz adsorbs barium from solution. This adsorption is a function of barium concentration and pH. 2—The presence of sodium, up to 6 millimol per liter does not materially affect barium adsorption at barium concentration of 0.06 millimol per liter.

Regarding laurate adsorption: 1—Quartz adsorbs

laurate from solution. This adsorption is also a function of laurate concentration but is independent of pH within the range 8.8 to 11.4. 2—An increase of sodium concentration causes a slight increase of laurate adsorption. 3—Laurate adsorption increases with great rapidity with barium concentration. 4—Laurate adsorption increases more rapidly with laurate concentration on barium-activated quartz than it does on unactivated quartz.

Regarding coadsorption of barium and laurate: 1—In barium activation and laurate flotation of quartz, the adsorption of activator is independent of the presence of collector. The reverse is not true. 2—Adsorption of barium and laurate on quartz is independent of the sequence of reagent addition. 3—The two-dimensional concentration of adsorbed barium is always greater than that of adsorbed laurate even at a laurate concentration in solution 30 times greater than the barium concentration.

Regarding flotation of quartz: 1—Flotation of quartz occurs at reagent concentrations such that the solubility product of barium laurate is not reached. 2—Flotation of quartz was observed with surface coverages of roughly 26 pct of a complete barium monolayer and 4.5 pct of a complete laurate monolayer.

Acknowledgment

This research work was made possible through the generosity of Armour and Co. in setting up the Armour Flotation Research Fund in the Dept. of Metallurgy, Massachusetts Institute of Technology. The authors wish to express their appreciation to H. M. Corley, Manager of New Products Department, J. D. Porsche, Director of Research and Development, and J. A. Barr, Jr., Manager of Chemical Derivatives Department, Armour and Co., and V. L. Parsegian, Director of Division of Technical Advisers, U. S. Atomic Energy Commission, for their invaluable encouragement. Acknowledgment and thanks are also extended to H. J. Harwood, Assistant Director of Research of Armour and Co., for his work in preparing the lauric acids, and to H. R. Spedden, R. Schuhmann, Jr., P. L. deBruyn, C. D. Coryell and J. W. Irvine, Jr., for their valued suggestions and criticism.

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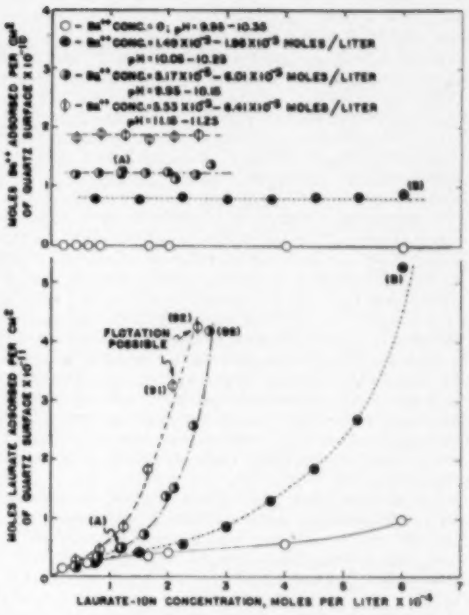
MOLES Ba++ ADSORBED PER CM² OF QUARTZ SURFACE X 10¹⁰
MOLES LAURATE ADSORBED PER CM² OF QUARTZ SURFACE X 10¹⁰
FLOTATION POSSIBLE
(A)
(B)
LAURATE-ION CONCENTRATION, MOLES PER LITER X 10⁻⁶

Fig. 12—Coadsorption, effect of laurate on barium activation and effect of laurate concentration on laurate adsorption of barium-activated quartz.

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Recent Coal Geology Research

by Aureal T. Cross

THIS paper is a review of the published literature on research in coal geology, principally exclusive of resource studies, which appeared or became available during 1950 and the latter part of 1949. This report is not to be construed as being complete. The papers referred to in the bibliography are those among many more, which were read either in full or in abstract.

Undoubtedly other papers were published which either escaped the author's notice or were not available to him. Those which were seen in abstract only (about one fourth of those listed) were not available in time for the inclusion of more than a notice.

An outline of all papers listed in the bibliography has been arranged by subjects and reasonable subdivisions with some papers cited under more than one subject. Most papers are indexed according to the principal subject of discussion or research only as to an unusual or noteworthy section of the entire report. There will likely be some disagreement as to the quality or merit of some of the papers selected and the specialist may be supercritical of the outline or organization of papers in his field. It may be that attention has occasionally been drawn to papers reporting old information or conclusions of questionable value.

Conferences and Meetings

One of the best indications of the growing interest in coal geology problems in the United States is the increasing number of times this field has been the focus of attention at conferences and meetings. Notable among these are the joint meeting of the Society of Economic Geologists and the Geological Society of America at El Paso, November 1949, at which the principal thesis was concerned with low rank carbonaceous fuel deposits, especially of western United States. Among the papers given which are already available were those presented by Barghoorn,[58] Parry,[120] Roe,[123] and Parks.[102]

At the annual meeting of the Botanical Society of America in New York, December 1949, a joint meeting of the Paleobotanical and Microbiological Sections was held for which a symposium on Microbiology in Relation to the Geologic Accumulation of Organic Complexes was organized. Publication of the six papers presented by Ralph G. H. Siu, Elso S. Barghoorn, Irving Breger, Claude E. ZoBell, James M. Schopf, and A. C. Thayson is anticipated. At the regular meetings of the Paleobotanical Section at the same time, several other papers of interest reported on coal ball studies, partial coalification of petrified wood, and floras.

In Chicago, April 1950, a symposium on Applied Paleobotany was held by the Society of Economic Paleontologists and Mineralogists in conjunction with the American Association of Petroleum Geologists. The five papers presented at this meeting dealt with the use of Paleozoic plant microfossils for stratigraphic work, J. M. Schopf, Devonian-Mississippian fossils of the black shales, Aureal T. Cross, Mesozoic plants of stratigraphic value, Th. Just, plant microfossils of the Tertiary, L. R. Wilson, and studies of the Brandon lignite, Elso S. Barghoorn. Early publication of these in the *Journal of Paleontology* is expected.

The Nova Scotia Research Foundation and the Nova Scotia Dept. of Mines sponsored an excellent 3-day conference in June 1950, which dealt with several aspects of coal geology. Papers on coal classification, P. A. Hacquenbard, structure and sedimentation problems in Nova Scotia, T. B. Haites, new techniques of thermal analysis, W. L. Whitehead, geochemical investigations of Nova Scotia coals, Irving Breger, the role of fossil plant spores in coal correlation and the stratigraphy of the coal-bearing strata of the Appalachian Region, Aureal T. Cross, were given. Some discussions of these papers by those in attendance were recorded, and the entire proceedings is being prepared for publication.

In September 1950, an unusual 3-day field conference was held by the Ohio and West Virginia Geological Surveys under the sponsorship of the Coal Geology Committee.[86] This study of the stratigraphy, sedimentation, and nomenclature of the Upper Pennsylvanian and Permian coal-bearing strata of southeastern Ohio, southwestern Pennsylvania, and northern West Virginia was augmented by two discussions on associated rocks (clays and shales) and stratigraphic nomenclature at Wheeling and Morgantown, West Va. An extensive guidebook was prepared, and transcriptions of the Morgantown meeting were made.

As a follow-up of the September field conference, a round-table discussion was held on this general topic at a special open meeting of the Coal Research Committee in conjunction with the November meeting of the Geological Society in Washington. Short prepared statements to invite discussion were given on each of several topics by L. M. Cline, Carl O.

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Discussion on this paper, TP 3247F, may be sent to AIME before March 31, 1952. Manuscript, Feb. 22, 1951. Joint session of Coal Division, AIME, and the Society of Economic Geologists. St. Louis Meeting, February 1951.

Dunbar, Harold R. Wanless, Wm. C. Krumbein, and Aureal T. Cross. The discussion leader, Monroe G. Cheney, encouraged free participation from the floor and about 15 persons entered into the discussion of problems of nomenclature, sedimentation, tectonics, and stratigraphy of Pennsylvanian and Permian strata of the Appalachian and midcontinent regions. The entire transcription has now been prepared and distributed to those who attended.

At the 1950 annual meeting of the Paleobotanical Section of the Botanical Society at Columbus in September, several papers were given on plant microfossils, coal balls, and general flora studies of coal-measures rocks. Of special interest were two studies on roof shale floras by Maxine Abbott on an Allegheny coal and A. J. Miklausen.[157] Three papers on plant microfossils and related modern forms were given by Mart P. Schemel (Missouri coals), John C. Ferm (Pennsylvania coal), and Clyde Reed (spore types). A special field trip for collecting typical floras from several Pottsville and Allegheny coals was conducted by Maxine Abbott.

Four foreign conferences were noted. The British Association for the Advancement of Science sponsored a meeting Aug. 30 to Sept. 6, 1950, at Birmingham University to deal with the concealed coalfields in the Midlands. A number of geologists participated in the discussion which considered coalfield extensions in faulted areas under as much as 3000 ft of cover.

A second conference on oil shale and cannel coal, July 3-7, 1950, at Glasgow, was sponsored by the Institute of Petroleum. The section on geology and mineralogy heard papers on difficulties of classification, R. A. Mott, Australian torbanite, J. A. Dulhunty, and a new Swedish venture in extracting oil shales *in situ* by electrical heating.

An international conference on classification of coal was held in Paris in February 1949, sponsored by the Coal Committee of the United Nations, at which an attempt was made to formulate an international classification of coals and standardized tests for coals.[68]

A conference was called in Geneva under the auspices of the Economic and Social Council of the United States.[71] Austria, Belgium, Czechoslovakia, France, Germany (western zone), Holland, Poland, Sweden, United Kingdom, and United States were represented. A classification was studied which would be based on two properties of coals, the content of volatile matter and swelling properties.

The Fourth World Power Conference, which was held in London in July 1950, dealt with preparation and production aspects of fuel and power, but several of the 180 papers given dealt with energy resources and microscopic studies and physical properties of coal.

New Research Laboratories

Several new laboratories with facilities and/or plans to conduct research in various phases of geological sciences allied with coal studies were instituted or formally opened during 1949 and 1950. Of the three of these important to Americans, the first is the Coal Geology laboratory established by the Fuels Division of the U. S. Geological Survey at Ohio State University, Columbus. James M. Schopf, who planned this fine, modern laboratory, is in charge. The second, which began operation in January 1949 in spacious quarters at Sydney, Nova Scotia, is sponsored by the Coal Division of the Geological Survey of Canada and the Nova Scotia Research Foundation. P. A. Hacquebard and T. B. Haites are in charge. The laboratory is well equipped to handle most problems except those in coal geochemistry. A third research center is the U. S. Bureau of Mines Lignite Research Laboratory, which was opened at the University of North Dakota at Grand Forks.

Three new foreign laboratories have been established in France, Spain, and India. An extensive laboratory at Verneul-sur-Oise, France, was to open in 1950.[160] It is planned to conduct extensive research and coordinate technical information in mining. The National Institute for Fuel in Spain has a new laboratory in connection with its headquarters at the University of Zoragoza.[9] A new laboratory, the Central Fuel Research Institute at Digwadhi in Bihar, India, was opened April 22, 1950. Extensive plans have been laid to conduct research in modern, well-equipped laboratories on colloids, chromatography, phyto-chemistry, electric and magnetic properties of coal, coal petrography, spectroscopy, X-ray, coal constitution, etc. This laboratory was opened just a year following the Birbal Sahni Institute of Paleobotany at Lucknow, a unique paleobotanical laboratory designed to bring together various paleobotanists of India for concerted studies, both economic and academic.

Numerous laboratories of various state agencies in United States were opened or considerably expanded their coal geology programs.

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Correction

In the December 1951 issue, p. 1068, TP 3194B, *Basic Laboratory Studies in the Unit Operation of Crushing* by J. W. Axelson, J. T. Adams, Jr., J. F. Johnson, J. N. S. Kwong, and E. L. Piret: The next to the last sentence in the last paragraph should read as follows: Rittinger's law is probably too simple a concept to encompass a complicated phenomenon and may very well not be a particularly desirable base or starting point for the development of a full understanding of crushing.

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aime NEWS

Minerals-Metals Groups Plan Northwest Conference

Plans have been completed with only details to be arranged for the first Metals Branch Conference in the Northwest. The two day meeting will be held jointly with the Industrial Minerals Div. on Friday and Saturday, May 9 and 10, 1952, at the Davenport Hotel in Spokane, Wash. For some time the metals activities in this area have been neglected. Expansion of metal producing and fabricating industries in Washington and neighboring states has brought sufficient interest to insure the success of such a meeting.

A committee has been hard at work for several months. Nonferrous extractive metallurgy men will find an extensive program in the April issue of JOURNAL OF METALS. Sessions for iron and steel producers, physical metallurgists, and educators will make the Metals Branch picture complete. Metals Branch members residing in Washington, British Columbia, Oregon, Idaho, Montana, Wyoming, Nevada, and Utah, or who can be in the Northwest at this time should make plans now to attend.

A Metals Branch luncheon is planned for Friday and a dinner jointly with the Industrial Minerals Div. is planned for Saturday according to F. R. Morral, metallurgist with the metallurgical research div. of Kaiser Aluminum & Chemical Corp., P. O. Box 1451, Spokane, Wash.

Annual Meeting Social Events

This is a tentative list of the social events of the Annual Meeting.

Monday, February 18

Welcoming Luncheon will have Harold R. Medina, famous jurist, as guest speaker.

Cocktail Party, Statler Hotel. The mining companies in the New York area extend a cordial invitation to the registrants and their wives to attend this informal get-together session. The **Dinner-Smoker** will follow the Cocktail Party at the Statler. Entertainment will be by Nelba of the Cotillion Room in the Hotel Pierre. Following the dinner, there will be an hour show by entertainers that will lend a night club atmosphere to the event.

Tuesday, February 19

Metals Branch Dinner, Keystone Room, Hotel Statler, preceded by an a la carte cocktail party.

Informal Dance, Hotel Statler. Music by 12-piece orchestra. Refreshments and entertainment during the intermission.

Wednesday, February 20

The Annual Banquet will be held at the Waldorf-Astoria Hotel. The banquet will be preceded by the President's reception and followed by dancing.

Section Delegates Amend Council Nominating Method

In accordance with instructions from the Feb. 17, 1951 meeting of the Council of Section Delegates at St. Louis, the Executive Committee of AIME drafted amendments of Articles 6 and 10 of the AIME bylaws. In September and October, these amendments were submitted to the delegates who, by mail ballot, voted the adoption of the amendments. The amended Articles are:

Article 6—There shall be one regular annual meeting of the Council at the time of the annual winter meeting of the Institute. This meeting shall precede, by a day or so, the scheduled Board meeting.

Additional special meetings may be authorized by the Executive Committee of the Council.

Article 10—The current Executive Committee of the Council shall constitute the Nominating Committee for officers and members of the Executive Committee for the following year.

In selecting the nominees, the Committee shall consider the principal professional interests as well as the geographic location of the nominees and shall keep in mind the necessity for rotating the nominees for chairman, vice-chairman and secretary through the three branches of the Institute.

The report of the Nominating Committee shall be submitted at the annual meeting of the Council, at which time additional nominations will be received from the Council at large. The election of officers will be by written ballot either at the Council meeting or by letter ballot at some time before November 1. The elected officers and members of the Executive Committee shall assume office on November 15 for a one year term.

Following the approval of these amendments, the Executive Committee acted as the Nominating Committee and submitted a slate of Council officers for 1952 to the delegates. By letter ballot, the delegates elected the following officers of the Council for 1952: Chairman—Jack A. Crichton (North Texas); Vice-chairman—Allan T. Cole (Florida); and Secretary—Merten I. Signer (Colorado). The Executive Committee nominations included W. C. Leonard (North Pacific), W. K. Bock (Cleveland), W. W. Leonard (East Texas), and C. Evans, Jr. (Pa. Anthracite).

Advances in Swedish Ore Mining Methods Discussed

Borje Hjortzberg-Nordlund, technical director, Trafikaktiebolaget Grangesberg-Oxelosund, is coming from Stockholm, Sweden, to present his paper "Trends of Underground Mining in the Great Export Mines in Sweden" at the Annual Meeting, AIME, Wednesday morning February 20. He has an international reputation as a mining engineer and this is an excellent opportunity to question him on some of the advanced Swedish mining practices. His paper is printed on page 187 of this issue.

AIME Annual Meeting Program, February 18 to 21, 1952

Statler Hotel, New York

Names of Divisions and Subdivisions are coded as follows: MIED—Mineral Industry Education Div. MED—Mineral Economics Div. M—Mining Subdiv. G—Geology Subdiv. Geophys—Geophysics Subdiv. NM—(Nonmetallics) Industrial Minerals Div. Coal—Coal Div. MBD—Minerals Beneficiation Div. IMD—Institute of Metals Div. ISD—Iron and Steel Div. Petroleum Branch—Named as such. SEG—Society of Economic Geologists.

SATURDAY, FEBRUARY 16

10 am to 5 pm
Council of Section Delegates

SUNDAY, FEBRUARY 17

1 pm
Student Relations Committee

2 pm
Board of Directors

2:30 pm
MIED—*Mineral Economics Instruction*

5:30 pm
MIED—*Cocktails and Buffet Supper*

7:30 pm
MIED—*Mineral Education*

8 pm
IMD—Program Committee

MONDAY, FEBRUARY 18

8:30 am
Registration

9:45 am to 12 m
MIED—*General Session*
M—*Drilling Symposium*
MBD—Business Meeting
NM—*Sulphur and Sulphuric Acid*
Coal—*Mining*
IMD—*Properties*
IMD—*Solidification and Physical Metallurgy*
EMD—*Copper and Lead*

10 am
Metals Branch Council

10:30 am
Petroleum Branch—*Technical Session*

12 m
Welcoming Luncheon, Judge Harold Medina, Speaker

2 pm
IMD—Executive Committee

2:30 pm
MED—*Foreign Development*
M—*Drilling Symposium*
G, Geophys—*General Session*
NM—*Ceramic Raw Materials*
Coal—*Mining*
MBD—*Milling Equipment*
Petroleum Branch—*Technical Session*
IMD—*Research in Progress*
IMD—*Orientation and Plasticity*
EMD—*Zinc*
EMD—*Training Extractive Metallurgists*

4:30 pm
IMD—Membership Committee

5:30 to 7 pm
Pre-Smoker Cocktail Party

7 pm
Dinner-Smoker

TUESDAY, FEBRUARY 19

7:30 am
IMD—Publications Committee Breakfast

8:45 am
Petroleum Branch—*Economics*

9 am to 12 m
MED—*New Production, Uses, and Trends*
M—*Open Pit Mining*
G, SEG—*Lead and Zinc Deposits*
Geophys—*Aerogeophysics*
NM—*Lime Production*
Coal—*Preparation*
MBD—*Materials Handling*
MBD, EMD—*Manganese Conservation*
IMD—*Theory of Metals, Seminar*
ISD—*General Session*
EMD—*Physical Chemistry of Extractive Metallurgy*

9:30 am
Women's Auxiliary Annual Meeting

10 am
Mining Branch Council

11 am
Howe Memorial Lecture, by Augustus B. Kinzel

12:15 pm
MIED—Luncheon
Indus. Min. Div.—Luncheon
ISD—Executive Committee Luncheon
EMD—Physical Chemistry Committee Luncheon
Mining and Metallurgical Society of America—Luncheon

2 pm
MED—*General Session*
M—*Canadian Mining Practices*
Geophys—*Aerogeophysics*
NM—*Portland Cement*
Coal—*Preparation, Heavy Density Symposium*
MBD—*Pyrolysis and Agglomeration*
MBD—*Flotation Theory*
Petroleum Branch—*Production Review*
EMD—*Physical Chemistry of Extractive Metallurgy*
ISD, EMD—*Manganese Conservation, Symposium*
IMD—*Theory of Metals, Seminar*

4 pm
Annual Institute Business Meeting
Coal—Executive Committee

5 pm
Directors Meeting, Executive
Indus. Min. Div.—Executive Committee

6 pm
Metals Branch—Cocktail Party

Evening
Metals Branch—Dinner
Petroleum Branch—Dinner
Informal Dance, AIME

WEDNESDAY, FEBRUARY 20

8 to 9:15 am
MBD—"Scotch Breakfast"

9 am to 12 m
M—*General Session*
G, SEG—*General Session*
Coal—*Utilization*
Coal—*Gasification and Liquefaction*
MBD, NM—*Beneficiation of Industrial Minerals*
MBD—*Operating*
Petroleum Branch—Executive Committee
IMD—*Crystal Structure*
EMD—*Addition Agents in Electrometallurgy*
EMD—*Physical Chemistry and Uncommon Metals*

9:30 am
Women's Auxiliary—*Round Table*

10:45 am
IMD—Annual Business Meeting

11 am
IMD Annual Lecture, by William Shockley

12:15 pm
M,G,Geophys—Luncheon
Coal—Luncheon
EMD—Executive Committee Luncheon
ISD—Physical Chemistry of Steelmaking Committee Luncheon

2 pm
M,G—*Exploration Drilling*
NM—*Geology of Industrial Minerals*
Geophys—*Engineering Geophysics*
Coal—*Gasification and Liquefaction*
Coal—*Geology*
MBD—*Crushing and Grinding, Operating*
MBD—*Flotation Theory*
IMD—*High Temperature Alloys, Panel Discussion*
ISD—*Oxygen in Steelmaking, Symposium*
EMD—*Addition Agents in Electrometallurgy*

4:45 pm
EMD—Annual Business Meeting

Evening
Annual Banquet
President's Reception

THURSDAY, FEBRUARY 21

9 am to 12 m
M, NM—*Mechanical Mining*
NM—*General Session*
Coal—*Gasification and Liquefaction*
MBD—*Crushing and Grinding, Theory*
IMD—*Transformation and Hardening*
IMD—*Constitutional Diagrams*
ISD—*Oxygen in Steelmaking, Symposium*
EMD—*Uncommon Metals*
EMD—*Addition Agents in Electrometallurgy*

12:15 pm
MBD—Luncheon
IMD—Powder Metallurgy Committee—Luncheon

2 pm
NM, SEG—*Economic Geology*
Coal—*General Session*
MBD—*Cleanup Session*
IMD—*Powder Metallurgy of Metal Ceramic Materials, Symposium*
IMD—*Physical Properties*
ISD—*Oxygen in Steelmaking, Symposium*
EMD—*Uncommon Metals*
EMD—*Addition Agents in Electrometallurgy*

THE DRIFT OF THINGS

by Edward H. Robie

MANY engineers currently are working harder than usual, in part because of the demands being made upon them for increased production in the war effort, and in part because engineers are in short supply so that there is more to do for those who are available. In some instances the question has come up as to what additional payment, if any, should properly be made for overtime work, and to what extent is such payment legally permitted under the rules of the Salary Stabilization Board.

Most engineers employed in an executive, administrative, or outside salesman capacity are not paid for overtime. They are paid for doing a job instead of for the hours they put in, and are free to do all the unpaid home work they feel they should do after dinner, as well as to do a bit of thinking and worrying during wakeful hours in bed. But engineers employed in a strictly professional capacity normally have standard office hours. Some employers pay for overtime and some don't. Their practice as it existed on Jan. 25, 1951 may be continued. In the absence of such practice at that time, the Salary Stabilization Board says that the engineer may now receive additional compensation up to his straight-time rate for an extended work week. No formal approval of the Board is required. "A professional engineer," in the mind of the Board, "is a person employed in a professional capacity, who, by reason of his special knowledge of the mathematical and physical sciences and the principles and methods of engineering analysis and design, acquired by professional education and practical experience, is qualified to practice engineering."

Inducted Engineers

A letter from a young man just inducted into the service and fearful that his engineering training is not going to be utilized reached us last week from Fort Riley, Kan. The AIME, cooperating with the other Founder Societies, is doing what it can, through the Engineering Manpower Commission, to see that engineers are not being wasted in the military establishment. So we passed this young man's letter along to T. A. Marshall Jr., executive secretary of that Commission.

Mr. Marshall tells us that the normal procedure now being followed by the Army in handling Selective Service inductees is to have them first complete 16 weeks of basic training before assignment to specialized categories. During that time they are classified. If one has an engineering degree he should be classified as scientific and engineering personnel at the end of the basic training period. He should then be transferred to a technical detachment and assigned an MOS (Military Occupational Specialties) reflecting his education.

If a young man is looking for a commission, it might be added that the current policy in the Army is to transfer to OCS (Officer Candidate School) applicants for commissions in the infantry only. The local unit commander can give information on this point, based upon the aptitude shown in tests. In view of the current shortage of engineers, it is believed that a young man should seriously consider remaining in enlisted status unless he can obtain a commission in a branch of the service that can make full use of his technical skills. His work may thus be more to his liking even if his uniform is not.

New York or Atlantic City?

In which place is it preferable to hold the annual meeting of a professional society like the AIME—New York or Atlantic City? That is, a winter meeting. The American Society of Mechanical Engineers has held its recent meetings at Atlantic City, with increasing attendance and satisfaction. The American Institute of Chemical Engineers chose Atlantic City for its recent December annual meeting. Only twice has the AIME ever met in this famous seashore resort: in 1898 and 1904.

Chief advantages of going to Atlantic City over New York are that technical sessions are better attended, there being little else to do there in Winter; the cost to members is less, and hotel facilities are better adapted to a large meeting. As to cost, take a banquet, for instance. The Chalfonte—Haddon Hall, which caters especially to winter conventions, charges about $7 for a banquet dinner of standard quality. A similar dinner at the Statler in New York would cost about $8.50, and about $10.50 at the Waldorf-Astoria. (The charge for tickets is somewhat greater than this because of the cost of music, programs, flowers, and other incidentals.) Rooms, too, are somewhat less at Atlantic City, two in a room being accommodated for about $7 per day each, compared with $7 to $10 at a headquarters hotel in New York. On the other hand, AIME headquarters is put to some extra expense for staff travel, food and lodging, and members living in New York and environs are forced to pay a hotel bill. New York, of course, has more varied amusements to offer, plenty of big stores, and the glamour of a big city.

The choice may be discussed at the forthcoming meeting in New York. In the meantime if any reader cares to express an opinion one way or the other we shall be glad to hear it.

College Scholarships

Most parents of children in the later stages of high school find it necessary to give some consideration to the cost of a college education. Although salaries have increased substantially it seems that the cost of the necessities of life, such as food, housing, and maintaining the family automobile, have gone up even more, so the problem of financing the children's education is as acute as ever. Many overlook the possibility of scholarships, or feel that only a student at or near the top of his class has a chance to get one. As a matter of fact, close to 150,000 scholarships and more than 15,000 fellowships, worth some $42,000,000, are available in 1200 American colleges and universities.

Those who are interested should send 55¢ to the Superintendent of Documents, Government Printing Office, Washington 25, D. C. for a 248-page publication just issued by the U. S. Office of Education, entitled "Scholarships and Fellowships Available at Institutions of Higher Education."

Personals

SOLOMON LIEB

Solomon Lieb has resigned as general superintendent of the Bolivian Tin & Tungsten Mines Corp., Huanuni, Bolivia. He is returning to New York.

John W. Miley is now engineer for the Telluride Mines, Inc., Telluride, Colo.

J. Howard Heginbotham has left for New Caledonia to become chief engineer working on the development of a chromite mine and mill to concentrate ore. The project is sponsored by the New Caledonia Metals Co. He will join **S. W. Norton**, resident engineer, for the project.

Frederick B. Brien has become ore testing engineer for the Hudson Bay Mining & Smelting Co., Flin Flon, Manitoba, Canada.

Samuel E. Watson is assistant general manager for the Andes Copper Mining Co., Potrerillos, Chile.

P. C. Benedict, geologist for the Newmont Mining Corp., is now located in New York. He had been in Johannesburg, South Africa for the firm.

Frederick W. Holshuher has been appointed controller for the Cerro de Pasco Corp., New York.

Keith Kunze, mill superintendent for the Central Eureka Mining Co., has resigned to accept a similar position with the Getchell Mines, Inc., Red House, Nev.

John D. Noll has joined the Oliver Iron Mining Co., Duluth, Minn.

Rodrigo J. Gomez has been promoted to design engineer at the Morenci branch of the Phelps Dodge Corp., Morenci, Ariz.

John McGuirk is now with Canadian Exploration, Ltd., Salno, British Columbia.

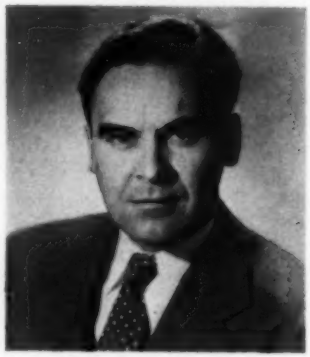
W. J. O'Connor, Sr., former Utah dept. manager, American Smelting & Refining Co. was elected president and general manager of the Independent Coal & Coke Co. **James W. Collins**, president of Tracy-Collins Trust Co. was elected as chairman of the board.

R. D. Bradford, western manager, American Smelting & Refining Co., has been elected president of the Utah Mining Assn. **J. Parnell Caulfield**, general manager of the Utah Copper Div., Kennecott Copper Corp., was elected second vice-president and director. **Cecil Fitch, Jr.**, vice-president of Chief Consolidated Mining Co. was advanced to first vice-president. **Miles P. Romney** has been made secretary-manager and **Oscar A. Glaeser**, assistant to vice-president in charge of western mining operations, U. S. Smelting, Refining & Mining Co., was elected director.

L. T. Higgins has resigned as concentration superintendent, Braden Copper Co., Chile, and is now residing in Toronto, Canada. He may be addressed at the Dominion Bank.

G. J. Bilstein is now manager of the Sucuitambo mine, Arequipa, Peru.

John Renning, Bureau of Reclamation, has been transferred from Ellis, Kan. to work on the Kirwin project at Kirwin, Kans.



WILL MITCHELL, JR.

Will Mitchell, Jr., former research supervisor in charge of four laboratories for Allis-Chalmers Mfg. Co., has been appointed assistant director of research. Mr. Mitchell joined the company in 1947 as director of the basic industries research and testing laboratory, now incorporated in the reorganized research div. He is secretary-treasurer of the Minerals Beneficiation Div., AIME.

Charles A. R. Lambly has resigned as general superintendent of the Pend Oreille Mines & Metals Co., Metaline Falls, Wash. He has accepted a position as assistant manager of the mining dept., American Metals Co., New York.

D. Gardner Foulke has been appointed executive secretary of the American Electroplaters' Society, Jenkintown, Pa. He succeeds **A. Kenneth Graham**, who resigned.

Frank McKinley, assistant superintendent of concentration, has left the employ of the Bunker Hill & Sullivan Mining & Concentrating Co., Kellogg, Idaho. He has joined the Humphreys Gold Corp. as plant superintendent of the Jacksonville, Fla. operation.

Roger V. Pierce, consulting engineer of Salt Lake City, has recently returned from an assignment at Minas de Matahambre, Pinar del Rio, Cuba. He will leave for Cerro de Pasco, Peru shortly.

Charles W. Connor is now defense solid fuels administrator, Dept. of the Interior, Washington, D. C. He had been manager of the mining div. for the Armco Steel Corp., Montcoal, W. Va.

Charles V. Harris is now employed by the Nickel Processing Corp., Nicaro, Oriente, Cuba, as superintendent of wet ore storage, drying and grinding.

Gordon B. Mackenzie has been appointed manager of Mineral Recovery, Ltd., Cornwall, England.

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ROBERT H. RAMSEY

Robert H. Ramsey, formerly executive editor of *Engineering and Mining Journal*, has been appointed editor and editorial director of *E&MJ Metal and Mineral Markets*. Mr. Ramsey has been on the staff since 1942.

H. A. Kursell, Scarsdale, N. Y. consulting engineer, has returned from professional work in Brazil and Peru.

R. C. Ried has retired from Knowles Associates, New York. **C. L. Knowles, R. Chelminski,** and **O. R. Kuster** are continuing the business.

William B. Plank, head of the mining and metallurgical engineering dept., Lafayette College, was presented with a certificate of appreciation from the Dept. of the Army for service on the Technical Industrial Intelligence Committee, Joint Chiefs of Staff. The certificate was for investigation conducted of enemy industry.

T. O. Evans, mining engineer with the Atchison, Topeka & Santa Fe Railway Co., Prewitt, N. Mex. is now at Los Angeles.

James E. Kuykendall is now associated with the Volcan Mines Co., Ticlio, Peru.

V. I. Mann is now a director and vice-president of the Neptune Gold Mining Co.

Thomas C. Baker has resigned as director of the foreign div., Defense Minerals Administration to join Canadian Exploration Ltd. He will be located in San Francisco.

G. C. Selfridge has joined the Defense Minerals Administration as chief of the ferroalloys branch of the Supply Div. He had been superintendent of the Fresnillo mine, Fresnillo, Mexico.

Robert P. Bremner, mining engineer with the Youngstown Sheet & Tube Co., has been named assistant to the

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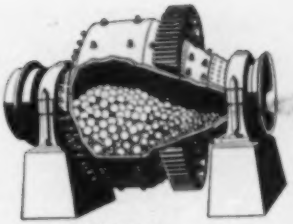
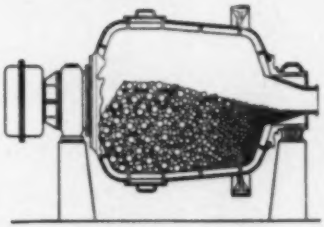
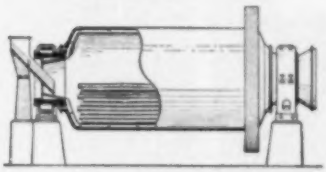


CONICAL . . . ?



TRICONE . . . ?



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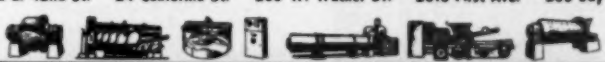

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CHELSEA R. PHILLIPS

Chelsea R. Phillips has been appointed field engineer for Hewitt-Robins, Inc., Hibbing.

Milton D. Moore, Jr. has joined John S. Lane & Son, Inc., Westfield, Mass., as assistant to superintendent of quarries. He had been associated with the National Gypsum Co., Bellefonte, Pa.

Kent R. Van Horn will succeed **Francis C. Frary** as director of research for the Aluminum Co. of America.

J. R. Van Pelt, president of the Montana School of Mines and director of the Montana Bureau of Mines and Geology, has been appointed an advisor to the Montana State Land Board on the allocation of mineral-bearing land.

Roy A. Bown, Montreal, Wis., has been named general superintendent of Montreal Mining Co. by Oglebay, Norton & Co., operating agents. He has been assistant superintendent, superintendent, and in charge of operations.

W. A. Pakkala has been appointed district superintendent of mines for the Cleveland-Cliffs Iron Co., on the Mesabi iron range. He succeeds **R. M. Belliveau,** who has resigned. **John J. Foucault** has been appointed superintendent of the Holman iron mine, Taconite, Minn.

H. C. Livingston, vice-president of operations, Union Pacific Coal Co., Rock Springs, Wyo., has resigned to accept a similar position with Truax-Traner Coal Co., Chicago. **Vernon O. Murray** has been named to succeed Mr. Livingston. Mr. Murray had been general manager of the firm.

James G. Hardy, formerly mill superintendent for Homestake Mining Co., Winterhaven, Calif., is now with Titanium Metals Corp. of America, Henderson, Nev. as production foreman.

Fred H. Stewart has been appointed general manager of the Southwest

Potash Corp. **W. Aubrey Smith,** formerly mill superintendent, has been appointed assistant general manager to succeed Mr. Stewart.

H. A. Johnson has resigned as mill superintendent for the Vermont Copper Co., South Strafford, Vt. He has accepted a resident managership for the Galigher Co. at Monticello, Utah.

A. K. Schellinger, formerly assistant professor of metallurgy at Stanford University, is now connected with the Cerro de Pasco Corp. as staff metallurgist.

E. G. Ross retired as mine superintendent for the Homestake Mining Co., Lead, S. D. **C. N. Kravig,** assistant mine superintendent since 1940 succeeded Mr. Ross and **W. C. Campbell** has been named assistant mine superintendent.

J. P. Sullivan has been made district manager of the Goodman Mfg. Co. Pittsburgh sales office to replace **R. C. Beerbower** who has retired.

John C. Kinnear, recently retired from Kennecott Copper Corp., has been named assistant for metals and minerals for Defense Mobilizer C. E. Wilson.

Royal B. Jackman has accepted the position as director of research of the R. T. Collier Corp. in Santa Clara, Calif. and is engaged in research on carbon products and chemicals.

Albert E. Forster has been elected vice-president and member of the executive committee of the Hercules Powder Co. He succeeds **Petrus W. Meyeringh** who retired because of ill health.

James L. Head has been elected president of the Mining and Metallurgical Society of America. **James Douglas** was elected vice-president and **D. M. Liddell** is secretary-treasurer. The councilors elected were: **Philip D. Wilson, Frank A. Ayer, Robert P. Koenig, Charles E. Stott, Harvey S. Mudd** and **J. D. Haffner.**

William Gardner Van Note is president of Clarkson College of Technology, Potsdam, N. Y. He had been director of the dept. of engineering research at North Carolina State College, Raleigh.

Elmer A. Jones has been promoted to assistant general manager for the Southeast Missouri Div., St. Joseph Lead Co. He had been assistant general mine superintendent of the same division.

Chester N. Traux, Jr., New Kensington, Pa. has been made an instructor in mining engineering at Lafayette College, Easton, Pa. Mr. Traux was previously in the engineering dept. of Allegheny & Pittsburgh Coal Co.

Thaddeus S. Ullmann, assistant export manager of the Eimco Corp., Salt Lake City, has returned to New York from a trip to western Europe. He visited the foreign subsidiaries and agents of Eimco Corp.

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GEOLOGICAL INVESTIGATIONS

Assistant Editor Wanted

A position is open in the AIME headquarters organization for a young engineer to do editorial work on MINING ENGINEERING and, possibly, other Mining Branch activities. Preference would be given to an engineer with ore dressing experience, but mining engineers ,geologists, and extractive metallurgists are also requested to apply. The primary qualification, other than a background of a minimum of two years' experience in the mineral industries, is an interest or aptitude for writing. The editorial work involves procuring articles of a news or technical nature; editing or rewriting them to meet magazine specifications; and supervising these articles and other sections of the magazine through all phases of magazine production. Applicants should apply to John V. Beall, c/o AIME, 29 W. 39th St., New York 18, sending experience records, references, photograph, and any special qualifications for the job. Date of availability and salary requirements should be stated.

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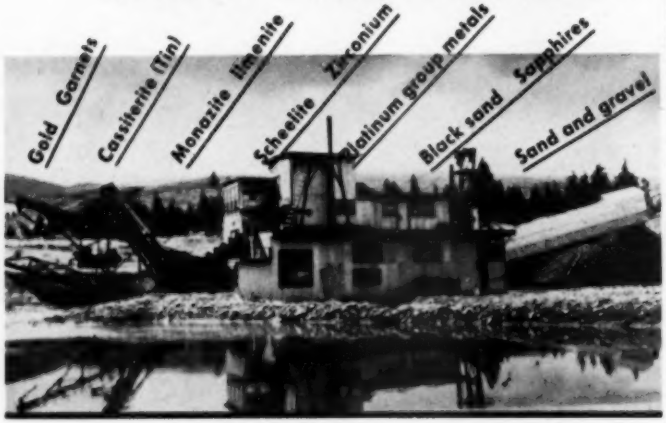

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—Coming Events—

Feb. 5, Society for Applied Spectroscopy, 6 pm, supper, Tosca's; 8 pm, meeting, Socony-Vacuum Training Center, 63 Park Row, New York.

Feb. 6, AIME, Chicago Section, Chicago Bar Assn., 29 S. La Salle St., Chicago.

Feb. 18-21, AIME, annual meeting, Hotel Statler, New York.

Feb. 19, Michigan College of Mining and Technology, alumni reunion, Skytop Room, Hotel Statler, New York.

Feb. 21, AIME, Utah Section, Newhouse Hotel, Salt Lake City.

Feb. 28, Bituminous Coal Research, Inc., annual meeting, Edgewater Beach Hotel, Chicago.

Mar. 3-7, ASTM, spring meeting and committee week, Hotel Statler, Cleveland.

Mar. 5, AIME, Chicago Section, Ladies' Night, Chicago.

Mar. 10-13, National Electrical Mfrs. Assn., spring meeting, Chicago.

Mar. 10-14, National Assn. of Corrosion Engineers, annual convention, Galveston.

Mar. 11, Society for Applied Spectroscopy, 6 pm, supper, Tosca's; 8 pm, meeting, Socony-Vacuum Training Center, 63 Park Row, New York.

Mar. 16-19, American Institute of Chemical Engineers, Atlanta Biltmore Hotel, Atlanta.

Mar. 17-21, ASTE, annual meeting, Chicago.

Mar. 20, AIME, Philadelphia Section, Engineering Bldg., University of Pennsylvania, Philadelphia.

Mar. 22-Apr. 6, Chicago International Trade Fair, Navy Pier, Chicago.

Apr. 1, Society for Applied Spectroscopy, Socony-Vacuum Training Center, 63 Park Row, New York.

Apr. 9, AIME, Chicago Section, Chicago Bar Assn., 29 S. La Salle St., Chicago.

Apr. 21-23, Chemical, Metallurgical, and Mining Society, and **Diamond Drilling Research Laboratory**, symposium on diamond drilling, Johannesburg, South Africa.

Apr. 22, Assn. of Consulting Chemists & Chemical Engineers, Inc., general symposium, Hotel Belmont Plaza, New York.

Apr. 25-26, AIME, New England Regional Conference, Kenmore Hotel, Boston.

Apr. 26-May 11, Liege International Fair, Liege, Belgium.

May 1-7, International Foundry Congress, Convention Hall, Atlantic City, N. J.

May 5-7, American Mining Congress, coal convention, Netherland Plaza Hotel, Cincinnati.

May 6-9, Scientific Apparatus Makers Assn., annual meeting, Edgewater Beach Hotel, Chicago.

May 9-10, AIME, joint meeting, Industrial Minerals Div. and Metals Branch, Davenport Hotel, Spokane, Wash.

May 11-14, American Institute of Chemical Engineers, Atlanta Biltmore Hotel, Atlanta.

May 22-24, American Society for Quality Control, annual convention, Onondaga County War Memorial, Syracuse, N. Y.

June 16-20, American Electroplaters Society, Industrial Finishing Exposition, International Amphitheater, Chicago.

June 23-27, ASTM, 50th anniversary meeting, Hotel Statler, New York.

July 1-Sept. 30, Centennial of Engineering, Chicago.

Sept. 11-13, American Institute of Chemical Engineers, Palmer House, Chicago, Ill.

Sept. 22-25, American Mining Congress, Metal and Nonmetallic Mining Convention and Exposition, public auditorium, Denver.

Oct. 22-24, Porcelain Enamel Institute, annual meeting, Greenbrier Hotel, White Sulphur Springs, W. Va.

NECROLOGY

Elected Date	Name	Date of Death
1948	Hellmuth R. Brandenburg	Nov. 29, 1950
1936	Oscar A. Dingman	Decem'r 1951
1947	Donald G. Lauck	May 1951
1925	C. R. Millar	June 1951
1937	Kenneth Moodie	Sept. 12, 1951
1922	James H. Morley	Apr. 1, 1951
1906	F. B. Nold	Unknown
1928	Norman F. Robertson	August 1951
1905	Benjamin F. Tillson	Dec. 4, 1951
1915	Albert L. Toenges	Dec. 19, 1951

Obituaries

Hellmuth R. Brandenburg (Member 1948) died at Reno, Nev. in Nov. 1950. He was born in Stettin, Germany. In 1919 he became chief chemist and plant operations manager for the Cowell Portland Cement Co. and remained with this firm for 23 years. Mr. Brandenburg maintained his private practice and in 1942 was engaged as consultant for the magnesium branch, Idaho Maryland Mines Co.

Thomas F. Hildreth (Member 1905) has died. Mr. Hildreth was born in Lockport, N. Y. in 1877 and at the time of his death was residing there. He was a student of chemistry at Columbia University and received his B.S. degree in 1901. He was employed by the Pittsburgh Steel Foundry, Glassport, Pa. for a short time and then became inspector for the Lackawanna Steel Co., Buffalo, N. Y. Later he joined the Ruthenburg Reduction Co., Niagara Falls, N. Y., as chemist. In 1912 he was manager of mines for the Davidson Ore Mining Co. at Buffalo. In 1917 he was made secretary and in 1929 was also treasurer.

Karl F. Hoffman (Member 1912), director of Placer Development Ltd., San Francisco, died in June 1951. Born at Oakland in 1877, he attended the University of California. Following graduation he was engaged in mine examination work and in 1903 was assistant to consulting engineer, H. Eckstein & Co., Johannesburg, South Africa. Several years later he was in Mexico as consulting engineer for A. Goerz & Co., Ltd., London. In 1914 he was in London and then returned to New York. He was employed by the General Development Co. and then joined the International Mining Corp., New York.

Charles E. Pettinos (Member 1944), head of Charles E. Pettinos, Inc., New York died on Nov. 15, 1951. Mr. Pettinos was graduated from Dickinson College in 1892 with the degree of M.A., Ph.B. He had been engaged in operating and financing graphite mines in Ceylon, Madagascar, Mexico, Canada, and the United States for over 40 years.

William N. Rossberg (Member 1914) died on Sept. 16, 1951. Born in Phoenix, Mich. in 1881, Mr. Rossberg received his E.M. degree from the Columbia School of Mines in 1904. Following graduation he was employed by various mining companies. In 1914

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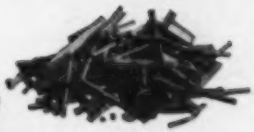

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he joined the Timber Butte Milling Co. as superintendent. In 1916 he was made superintendent of the Elm Orlu Mining Co. and in 1918, became manager of both firms. Mr. Rossberg was promoted to general manager in 1920. He remained with this firm for several years and in 1934 joined the Flotation Research Corp., Los Angeles, as vice-president. At the time of his death he was residing in Beverly Hills, Calif.

Paul Semko (Member 1948) has died. Mr. Semko attended Lafayette College and received his degree in geology in 1948. He was employed by the Pennsylvania Turnpike Commission, supervising diamond core drilling and making geological reports.

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Total AIME membership on Nov. 30, 1951, was 17,403; in addition 2079 Student Associates were enrolled.

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The Institute desires to extend its privileges to every person to whom it can be of service, but does not desire as members persons who are unqualified. Institute members are urged to review this list as soon as possible and immediately to inform the Secretary's office if names of people are found who are known to be unqualified for AIME membership.

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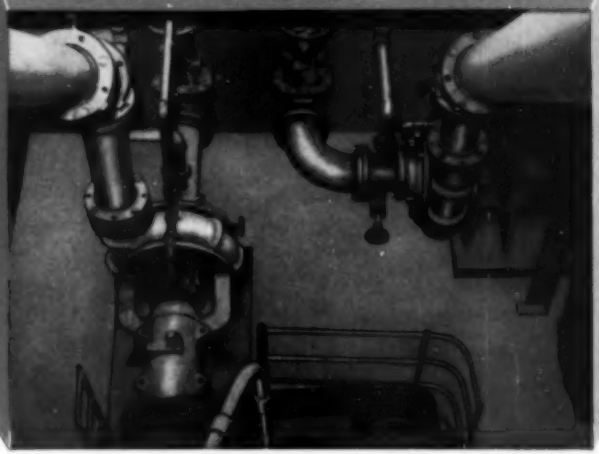

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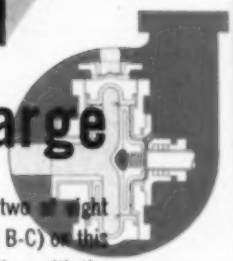

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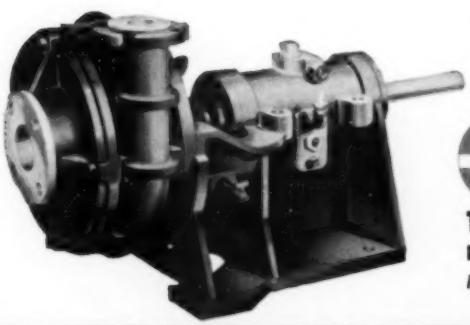

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